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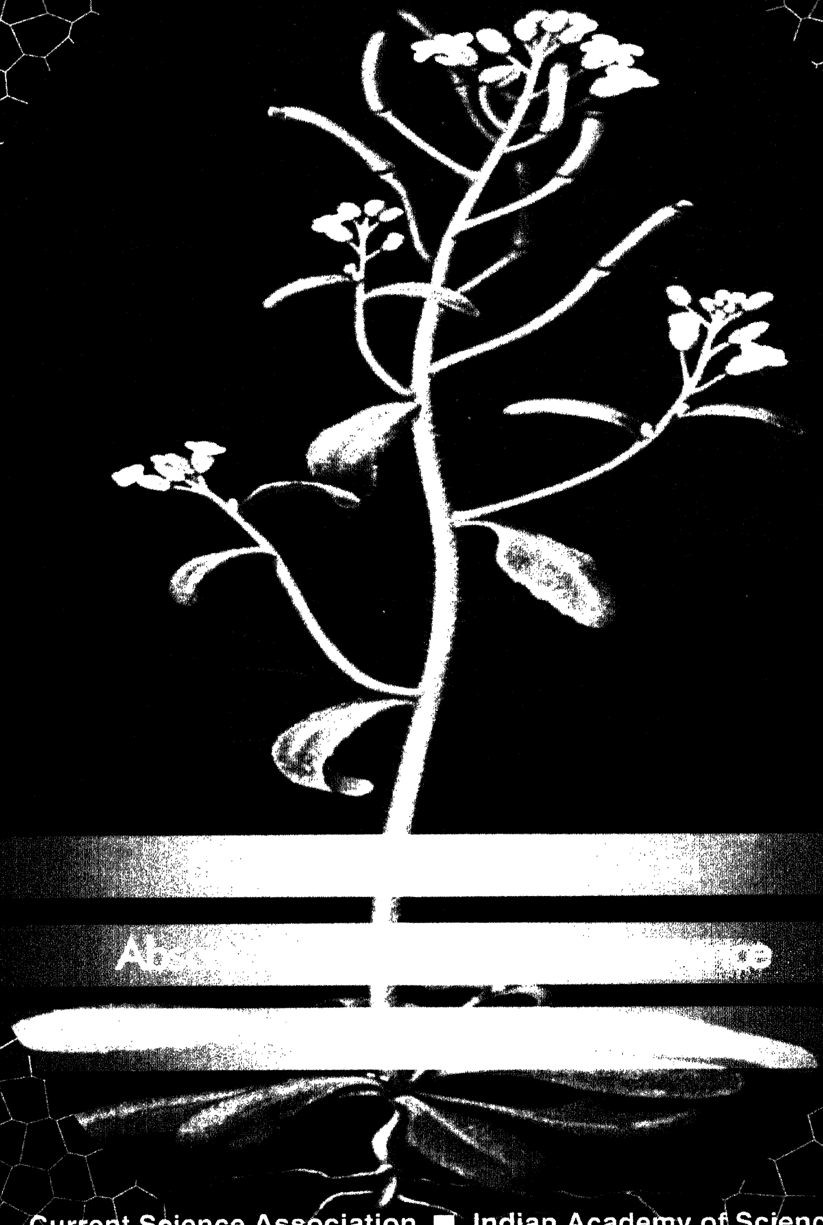
10 May 1999

CURRENT SCIENCE



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2. Constantine. G., in *Biology of Bats* (ed. Wimsatt. W. A), Academic Press, New York. 1970. vol 1, pp. 319–322.

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Research News	Less than 2000 words; display items should be restricted to 2 Figures and 1 Table
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General Article	About 4000 words; 6 display items
Review Article/Research Account	About 6000 words; cited references should be limited to 100
Research Article	About 4000 words
Research Communication	About 2000 words
Book Review	Less than 1500 words

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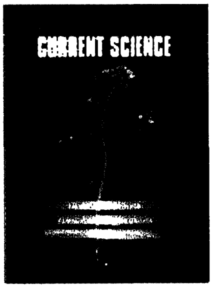

COVER. *Arabidopsis thaliana* is a small plant of Cruciferae (Mustard family) that is being used in hundreds of laboratories worldwide as a model for studying plant biology. *Arabidopsis* offers many advantages for genetic and molecular studies, including short-life cycles, small genome, ability to be transformed, wide-spread availability of mutants and prolific seed production. See page 1220.

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In this issue

Tracking life science research

The availability of computerized databases has made the analysis of research output easier and more quantitative. Publication statistics are very popular (?) amongst scientists; reminding us at least, in this season, of children and their fascination for cricket statistics. What is not commonly appreciated is that the statistics of publications can be dangerously misleading, if the limitations of the underlying database are not well understood. Classification of journals into a specific discipline is very difficult nowadays. For instance, medical research databases include many journals dealing exclusively with basic biology and biochemistry. Important papers on magnetic resonance imaging may appear in physics or chemistry journals, which do not find a place in the roster of medically oriented publications. Nevertheless, many sub-databases exist which can be used for reasonably reliable mapping of scientific output.

Arunachalam (**page 1191**) uses the *BIOSIS* Biological Abstracts database (1992–94) for mapping 'Life Science' research in India. The subject is important since funding agencies have been consciously supporting research in this area since the early 1980s. A major problem of course is to define what constitutes 'life sciences'. The indexation procedure of the *BIOSIS* database allows 'biologically' oriented papers from a wide variety of 'non life science' journals to be included. The database is fairly large and allows many interesting conclusions to be drawn.

One inevitable feature of these analyses is that they remind us that the fraction of papers from India published in highly visible ('high impact') journals is small. This is a well-known and widely discussed fact. Arunachalam's paper is full of many nuggets of information, which can be interpreted in different ways. He also makes some conclusions which may stir debate. For instance, he says 'What should be of concern to policy makers and funding agencies is that even scientists from better-known institutions publish a large number of papers in journals not indexed in *SCI*'. Most of these 'non-*SCI*' journals originate in India, leading to the uncomfortable question whether these journals and the papers they publish serve a useful role at all. Should the *SCI* be the overriding determinant of publishing practices? Arunachalam draws some perceptive conclusions. He identifies two distinct clusters of institutions: one 'working on classical biology and agriculture' which 'concentrate on certain sub-fields and publish often in journals of low impact and another smaller cluster of institutions working on new biology publish part of their papers in high-impact journals'. The author points out that 'at the moment there seems to be very little overlap between the interests of the two clusters'.

Ribosome mediated folding

Christian Anfinsen is credited with the idea that the information necessary for folding protein structures is entirely encoded in the sequence of amino acids that make up the polypeptide chain. The efficient refolding of many proteins *in vitro* supports the idea that proteins do not need the assistance of other cellular components to acquire native three-dimensional structure. The discovery of cellular proteins, molecular chaperones, which assist folding in cells (and in many cases, folding in test tubes) was a major advance in biochemistry. The first crystal structures of chaperones quickly provided clues to their functioning, leading to models where their role is essentially passive, providing a nascent polypeptide chain a sequestered environment, preventing non-productive protein aggregation. The first report that ribosomal components can promote protein folding came from the work of Chanchal Das Gupta at the University of Calcutta. This observation has major implications for cellular processes since the ribosomes are indeed the site of polypeptide synthesis.

On **page 1235** Chakrabarti *et al.* examine the structure of a model protein, horseradish peroxidase (HRP), during ribosome mediated folding. Their results provide 'evidence of direct physical association between the ribosome particle and denatured HRP during refolding'.

P. Balaram

Tuberculosis

Tuberculosis is known as 'King of diseases' today – although the adjective itself is a kind of oxymoron!. No disease should ever be referred to as a King. If the population with low purchasing power is affected by a particular disease, it does not draw attention of the multinational drug companies. Tuberculosis was thought to be one such disease even in recent past. However, the scenario has changed; now the most affluent nations are alarmed with the increase in the number of tuberculotic patients. The worst fear has come true. The bacteria appears to be extremely smart to evade the action of drugs like isoniazide and rifampicin. Thus, there is a renewed vigour to search for new drugs or new metabolic pathways which are affected due to mycobacterial infection.

The mechanism of action of the drug rifampicin has very well been worked out. It acts on the β-subunit of bacterial RNA polymerase, thereby inhibiting the transcription process. All the rifampicin-resistant mutants always have altered *rpoB* gene, which codes for the β-subunit of RNA polymerase. However, some bacterial strains with low resistance to rifampicin have been found with no alteration in the β-subunit, indicating thereby other cellular components which are responsible for drug resistance.

Geetha Ramachandran *et al.* (**page 1231**) have now discovered that drug-resistant tuberculosis strains show elevated level of cytochrome P-450 in comparison to that of sensitive strain. Cytochrome P-450 constitutes the most powerful oxidizing enzymes and is involved in the biotransformation of a wide variety of drugs and is found in liver microsomes.

The authors have been able to assay cytochrome P-450 spectrophotometrically and have shown that its level is significantly higher in the rifampisin-resistant strain of *M. tuberculosis* and in its other variants. It is then responsible for quick degradation of the drug rendering it ineffective? The question which remains unanswered is whether there are inhibitors of cytochrome P-450 which will competitively leave out the drugs from metabolizing in a mixed assay system. Any new angle towards efficient handling of tuberculosis infection always appears to be a welcome change.

D. Chatterji

CURRENT SCIENCE

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EDITORIAL

Sanctions

It is almost a year since sanctions were imposed by the United States, Japan and some countries of Western Europe, following the Pokhran explosions. While the sanctions were primarily targetted at laboratories associated with strategic research programmes, there have inevitably been some effects felt by institutions largely concerned with basic research. For example, the Tata Institute of Fundamental Research (TIFR) in Mumbai is almost exclusively devoted to 'blue sky' research, but is funded directly by the Department of Atomic Energy (DAE). The historical association of TIFR and the DAE, of course, dates back to the days of Homi Bhabha. This relationship has been a very fruitful one, with the TIFR budgets being insulated from the many uncertainties faced by institutions outside the DAE umbrella. Unfortunately, connection with the DAE now means that even scientists doing basic biology, chemistry or physics (mathematicians, fortunately are apparently immune to the effects of sanctions) face great difficulties in getting chemicals and equipment from several overseas sources. Even the Tata Memorial Hospital, which is exclusively devoted to cancer therapy, appears to be suffering because of its DAE connection. Sanctions have also led to completely unacceptable behaviour on the part of several companies which refuse to provide warranty replacements for expensive equipment which has already been paid for. The official position (understandably) has been that sanctions are having no effect. In reality, however, there will be pockets of scientists whose individual researches are being affected by the non-availability of materials.

There is little doubt that sanctions are a knee jerk reaction to the nuclear explosions. Are wide ranging sanctions justifiable? How do we minimize the impact of sanctions? These questions should be broadly addressed. It does not help to say that sanctions do not exist or that they are without any effect on our scientific research. Even more importantly we must assess our own response to countries and companies which have proceeded to impose restrictions on the flow of materials and sometimes, even on the travel of scientists. Several months after the explosions a group of American high-energy physicists from Fermilab were denied permission by the US Department of Energy to attend a conference at TIFR, an action clearly inconsistent with the norms of international scientific exchange. What has been really surprising is the complete silence of Western scientific bodies to actions which are intended to curb free, unfettered international scientific discourse. Even the voice of individual scientists has been strangely muted. A notable exception was an editorial in *Science* (1999, **283**, 184) by Irving A. Lerch which did conclude: 'The efforts of government officials to slow this engine of exchange under the disguise of preventing weapons technology transfers threaten debilitating consequences for science here and abroad'. The present indifference of international unions and scientific societies is in marked contrast to their apparently activist stances in the past. Many of these bodies have always been the most vocal in their protest, when there has been the slightest indication that freedom of travel to scientific meetings has been curbed. Most notably, during the apartheid era, the scientific unions invariably dominated by the West, were foremost in demanding the entry of South African scientists (white, of course) to conferences in India. The countries that are the foremost proponents of sanctions are also the very same countries which have no difficulty in shipping scientific equipment and chemicals to many countries possessing nuclear weapons (and research capabilities in this area).

What have our scientific bodies been doing to build pressure in the international scientific community against sanctions? From the public record at least, nothing seems to be happening. The Indian Science Congress played host in January at Chennai, to Bruce Alberts, the President of the US National Academy of Sciences (NAS). Whether the position of the NAS on sanctions was probed or not is unclear. There have been no public statements on this issue, which are intended to give the feeling that Indian scientific bodies are going to lobby vigorously with their counterparts elsewhere. The Indian National Science Academy which holds a unique position in representing this country on international unions has a special responsibility in coordinating efforts to rally support in the international scientific community against sanctions, which affect research in all areas, indiscriminately. At the same time we must also carefully evaluate the pros and cons of many international exchange programmes that we have with the countries imposing sanctions. It is also time that efforts are made to help those Indian scientists, whose work is affected, by some collective action.

P. Balaram

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Withering of science in engineering education

This letter refers to the latest syllabi of the first year BE (Bachelor of Engineering) courses of Universities in Tamil Nadu. Unlike the previous pattern, the core (common) syllabus has been changed and the new syllabus varies from University to University. The new syllabus is less relevant for engineering education because most of the universities neglect basic sciences. In Bharathiar and Bharathidasan Universities, the four important basic science subjects, viz. applied physics, applied chemistry and their practical subjects have been reduced to physical science theory and laboratory. This shows the declining interest towards science in engineering education. Some universities (Madras, Madurai Kamaraj and other State Universities) are still having physics and chemistry along with practicals.

Science is very important for engineering education and engineering students must study basic sciences as separate papers. Most of the institutions like IIT, BITS Pilani, Roorke University, Anna University, etc. have engineering physics and engineering chemistry as separate papers.

The following points should be kept in mind while preparing the engineering curriculum: (i) The syllabus committee should consist of all subject experts including mathematics, physics and chemistry. Individual ideas should not be reflected in the syllabus; (ii) Science is important for maintaining and improving technology. Hence, all the engineering students should study basic sciences; (iii) Basic sciences with common syllabus will be helpful for the students, even for their future employment; (iv) AICTE must define certain criteria regarding the BE syllabus, in which the percentage of science subjects should be clearly mentioned; (v) The state board for higher education or technical education body should form a committee for formulating or revising the syllabus; and (vi) The proposed syllabus should be submitted to the AICTE, to be finalized.

The Government should form a committee to analyse the revised syllabus of all universities in Tamil Nadu. Steps must be taken to prevent neglect of science in engineering education. I appeal to the DTE (Directorate of Technical Education), HES (Higher Education Secretary) and AICTE authorities to bring a common syllabus for all universities. At least, the science subjects should be the same for all the universities. AICTE must improve the standard of the BE syllabi of all the southern universities. Will the AICTE look into this?

K. KANIAPPAN

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India in 2020

I have been highly impressed by the exciting optimism expressed in the recent book *India 2020 – A Vision for the New Millenium*.

A news-item about the risk of 'tech colonialism' by C. N. R. Rao on the occasion of the dedication of 'PARAM-10,000' on 19 March 1999, urges me to pen down the reactions of an academic scientist who has struggled to contribute his mite in ordinary universities for the past 55 years. Originating from A. P. J. Abdul Kalam with Y. S. Rajan after astounding success in high profile national indicators like satellite or/and missile launch as well as after long deliberations in TIFAC, one should have full faith in their optimistic vision for 2020. However, having been an active worker in the university system (including UGC) with the added advantage of close association with the highest bodies (e.g. G. B. and laboratories) of CSIR, I would like to re-emphasize the conclusion of Kalam and Rajan, 'India will transform into a developed nation before 2020. A billion people are our resource for this national transformation'.

The second generation to which the authors belong (cf., p. 22 of the book) 'has put India strongly on the path of economic, agricultural and technological development'. However can this second generation to which I also belong have similar expectations from the coming generations, which in my personal opinion are even more brilliant basically. Hopefully, a few flourishing centres like IISc, JNCASR, TIFR, IACS, etc. continue to be our hope for the future but can these few institutions alone deliver the results on the massive scale envisaged by the authors. For the past few years, CSIR has been successful in the competitive growing era of specialization (including patents), but the general university system which is the source of original thinkers even for manning such organizations, is becoming an increasing source of worry to even persons like us who have been struggling hard not to lose faith in our younger generation. The authors of the book have also rightly emphasized (just in passing) the golden triangle of 'industry – R/D lab – academia' and there has been considerable debate on the topic in various forums including *Current Science*, but there are no visible signs for the same to be effective on the ground particularly in the latter two aspects.

Another closely related point emphasized at the dedication of PARAM-10,000 is that focussed attention on the development of new (not merely borrowed) technologies could probably be achieved with greater success in areas in which the developed countries might have lower fascination due to non-availability of source-materials like titanium and rare earths, etc. Success stories in these directions would be a source of encouragement for more competitive fields.

The purpose of this brief note is to encourage a continuing debate and effective steps to remedy the situation before it is too late for the 'vision-2020' to be a reality.

R. C. MEHROTRA

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The enigma of insect conservation

Increasing interest in the production of comprehensive mapping schemes involving the most conspicuous groups of insects is a step in the positive direction, since such efforts reflect the nature of the collecting sites as well as the distributional range of species. Though the world plant biomass is 99.9 times that of animals, the latter make up 99.8% of species and among these insects dominate all ecosystems. The significance of plant–insect mutualism cannot be overlooked since pollinating insects maintain plant biomass in as much as plant diversity contributes to pollinator success with resultant interactive increase in biotic richness[1]. Spatial scales in relation to insect conservation becomes relevant and enough evidence exists to show the diversity of scales used from 1, 10 or 100 m to km^2 ranges, the latter often giving a good picture of insects such as butterflies, dragonflies, crickets and grasshoppers. The extent of landscape interference through fragmentation mostly due to deforestation naturally leads to an assessment of available elements of landscapes such as microsites and biotopes within the available plantscape. This is important since the degree of heterogeneity in populations as well as intra- and inter-specific interactions are involved so that consideration of biotopes becomes important, since it covers the physical and biotic components wherein insects live. The need for conservation of small insects which abound in both species and population is equally vital. Within the mapping site specific plantscape and biotopes have to be considered more in view of the fact that many small insects have comparatively small home ranges.

For small-scale environments the term 'microscape' is used, so that the microscape to the plantscape or plant architecture becomes important in insect biodiversity studies, since at scales from metres to kilometres biotopes make up landscape elements so that heterogeneity tends to increasingly contribute to conservation efforts. From the conservation viewpoint therefore, insect habitats from micro- to macro-habitats have to be conserved. Many species which are biotope-sensitive suffer the consequences of anthropogenic factors which induce changes. I had worked in the Thenmalai area of the Western Ghats in the early sixties when the vegetation was lush. Subsequent comparison two or three decades later, particularly of the composition of species of gall thrips and mycophagous thrips, has indicated the virtual disappearance of several species, some of which were good examples of discontinuous distribution. In view of many species being endemic there should be an intensive effort to document all endemic species belonging to diverse insect groups in such areas. There also exists the high levels of genetic variation in natural populations with adaptive responses particularly in relation to sex-related polymorphism and diversity of patterns involved in such polymorphism is often great, calling for the need to keep in mind the existence of such diversities and also involve specialists who alone can predict the occurrence of such diversity[2]. Of equal relevance are species occurring alongside margins of their ranges with differing physical and biotic conditions and these populations are liable to dwindle due to environmental causes. Therefore, conservation of appropriate habitats would appear more meaningful in insect conservation rather than on the basis of species and as has been rightly asserted 'conservation decisions rest essentially on the interpretation of field data into biological reality'[3].

Conservation biology is essentially a 'crisis science' needing specialists to justify the need for conservation in terms of their usefulness. In view of the demarcation of well-defined biosphere reserves, a beginning could be made through integrated efforts to study the range of disturbance levels in these reserves to conserve groups of insect species. Further, the maintenance of biodiversity succession is also an important parameter in natural ecosystems, since insects and plants are more often the primary determinants of succession patterns. It would also be an useful exercise to become involved in long-term monitoring of insects in specific habitats such as in biosphere reserves with emphasis on individual species to know their responses to change, as well as other species in the community.

There is a need to protect water bodies such as lakes and wetlands which are being threatened by various factors and which are sources of insect reservoirs. A comparison of such disturbed water bodies in our own hill resorts all over the country becomes all the more relevant in view of increasing anthropogenic influence.

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Creative science

Shiv Viswanathan in his article 'The tragedy of K. S. Krishnan' (*Curr. Sci.*, 1998, **75**, 1272–1275) mentioned that 'Ashish Nandy's *Alternative Science* showed that Jagadish Chandra Bose eventually succumbed to the pressure of being original and fabricated his data'. I have read the above-mentioned book and found no such statement. There are *unsubstantiated* statements such as 'he refused to see the experimental results his colleagues obtained if the results contradicted his own ideas' (p. 51) and 'Bose began to stretch his experimental results and to force his associates to do the same' (p. 55). This is not the same as fabricating data. In a book with pretentions to scholarship, replete with footnotes, why is there no evidence for such statements?

It is not Bose but Nandy who succumbed to the pressure of trying to find an original psychological angle of debunking. The book contains many references to Bose's failure as a scientist.

Nandy begins Part I with the lines, 'I met Jagadish Chandra Bose accidentally'. One does not need much time to discover that he means this metaphorically! Later he says he is in no position to judge Bose's scientific contributions, but sallies forth nonetheless. The passage of 20 years has shown how shallow was his judgment; Bose's discovery of millimetre wave radiation and his work on Schottky barrier detectors (American patent!) were enough to establish him as a giant of the times – one whose observation of negative and positive effects in coherers was a precursor to the discovery of *p*- and *n*-type semiconductors. Should we listen to Neville Mott who said that 'J. C. Bose's discoveries were 60 years ahead of time', or should we heed Nandy?

Nandy's search for controversy is apparent when he refers to Sister Nivedita. He writes on p. 45, 'the relation between the nun and the scientist gradually turned into a deep – I am sorry to disappoint the reader – platonic bond'. Nandy would be well advised to explore the relationship between Madame Curie and Paul Langevin. It is time we stopped referring to this flawed piece of muckraking – hardly a good example of providing 'backstage' information and nothing more than a simplistic Freudian analysis.

What motivated Bose to switch to biology? According to Nandy it was 'visions of a grand defeat and what could be paradoxical fear of negative success...'. Nandy in his ignorance is not aware that such switches have occurred many times – Donald Glaser, after a Nobel Prize for the discovery of the bubble-chamber and most recently John Hopfield, going over from particle and condensed matter physics, respectively to biophysics. When Bose turned to the study of plants, he was returning to his first interest – life sciences – since he went to England originally to study medicine. His experiments were path-breaking at the time, no matter that the basis did not exist for correct explanations. As to what is success – most *great* scientists seek out challenging problems and often fail in their final endeavour – witness Heisenberg's approach to unification, (not to mention Einstein) and Raman's theory of colour perception.

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NEWS

Waterman Award for Chaitan Khosla

Chaitan Khosla, 34, Professor of Chemical Engineering and Chemistry at Stanford University, California, is to receive the 1999 Alan T. Waterman Award of the US National Science Foundation (NSF). The award named after NSF's first director is intended to honour an outstanding US scientist below the age of 35. The award carries a $500,000 research grant for study in any field of science or engineering.

Khosla, an alumnus of the Indian Institute of Technology, Mumbai, received his B Tech degree in 1985 and subsequently obtained a Ph D at Caltech. He has been honoured for his remarkable work on genetic engineering of polypetide biosynthesis which has opened the way for production of new antimicrobial agents. Khosla is credited with pathbreaking work on erythromycin biosynthesis and elucidating molecular mechanisms which has now led to great interest in the production of novel antibiotics. Commenting on the award to Khosla, University of California-Berkeley chemistry professor Peter Schultz said that 'Khosla's creativity, productivity and intellect are defining the forefront of his field and opening a whole new opportunity at the interface of chemistry, biology and chemical engineering.

American Physical Society celebrates a centennial

A number of Societies of Physicists have been around for more than a century; these include Societe' Francaise de Physique founded in 1873, Physical Society in UK from around 1874, Italiana di Physica founded in 1897 and so on. The American Physical Society joins this group of centenarians now.

The American Physical Society was founded on 20 May 1899 by holding its first meeting at the Columbia University, New York City. According to A. Pais in *Inward Bound*, 'In 1899, the American Physical Society was founded by 38 physicists. In 1900, the world wide number of academic physicists of all ranks was about 1000. The number of theoretical physicists was 8 in Germany, 2 in USA, one in Holland and none in the British Empire. The emergence of theoretical physics as a semi-autonomous discipline is a 20th century phenomenon'. As Pais states, around 1895, 'none of the fundamental particles had yet been found, cosmic rays had not been discovered, the only accelerator was a cathode ray tube and relativity theory and quantum theory were yet to come'. At the 20 May 1899 meeting, the physicists elected from their midst two colleagues of international reknown as Senior Officers: Henry Rowland as President and Albert Michelson as Vice-President. Neither Rowland nor Michelson had formally earned a Ph D degree.

Today American Physical Society is one of the foremost bodies that is active and has to its credit several achievements. It has over 40,000 members and it is one of the ten member societies of American Institute of Physics founded in 1931 'for the purpose of coordinating various societies whose interests are primarily in the field of physics and for the purpose of supporting their publications'.

A special issue of *Reviews of Modern Physics* was published in March 1999 in honour of this centenary of the American Physical Society. In the Preface to this issue Benjamin Benderson of the American Physical Society states 'this American Physical Society issue can be considered as a companion volume to the collection entitled *The First Hundred Years* edited by H. Henry Stroke, containing about 1000 articles reprinted in hard copy and by CD-ROM in 1997, published by the American Institute of Physics to commemorate the centenary of *Physical Review* whose birth preceded that of American Physical Society by three years'.

The special issue of *Reviews of Modern Physics* contains about 50 articles covering historical developments, astrophysics, nuclear physics, atomic, molecular and optical physics, condensed matter physics, statistical physics and fluids, plasma physics, chemical physics and biological physics and application of physics to other areas. The section on historical developments contains articles, more like eye-witness accounts prepared by persons who played important roles in their developments like Hans Bethe, A. Pais and W. Kohn. Each one of these articles brims with personal ring-side view of developments and helps to provide a proper perspective of growth of important topics of physics. In a short introduction, Hans Bethe says 'a hundred years ago, some of the great physicists in England and Continental Europe predicted that physics was at an end. We know what actually happened and we are proud of the contribution of American Physical Society.... Looking at the predictions of 100 years ago, it would be foolish to make predictions for the next 100 years.'

RESEARCH NEWS

Evidence of electrochemiluminescence as a pumping mechanism for a dye laser

Sushil Mujumdar

An important advancement in the technology of continuous wave dye lasers was reported by a group of scientists at NTT Basic Research Laboratories, Japan[1]. They claim to have realised an idea, proposed about twenty five years ago, of improvising the process of pumping a dye laser, thereby making the family of dye lasers easier to maintain, cost effective, and user-friendly.

For any medium to act as a laser, it is essential that the number of molecules in the excited state exceeds the number of molecules in the lower state. This condition is called 'Population Inversion'. In ordinary circumstances, the energy levels are populated according to the Maxwell Boltzmann distribution. This distribution rules that the population of any energy level is inversely proportional to the exponential of its energy. Furthermore, the excited states have a very short lifetime, and the molecules in the excited state decay rapidly to the lower state, destroying the population inversion. So, to hold a large number of molecules in the excited state, one is required to supply a lot of energy. The minimum energy required to invert the population is called the threshold energy. The obvious sources of such large energies are flashlamps. However, flashlamps can deliver energies only in short pulses, and cannot perform continuously. They are used, therefore, in pulsed dye lasers. And This is where continuous wave dye lasers run into problems.

The active medium in dye lasers is a fluorescent dye, the molecules of which absorb energy in the blue part of the spectrum, and emit in the red part. Every electronic energy level of the dye consists of a stack of vibrational levels which are closely spaced and almost form a continuum of states. Hence both the absorption and emission spectra are continuous. That makes the dye lasers tunable, i.e. one can obtain a laser emission at any wavelength within the fluorescence spectrum. This is a powerful advantage over other lasers.

Dye lasers, being the tunable type, are vastly used in areas such as spectroscopy, light scattering and find applications in medicine, communications etc. However, these dye lasers can prove to be a liability than an asset, because of the pumping requirements.

The source which can deliver high energies continuously is a laser itself. So, to build a continuous wave dye laser, other lasers are used as pumping sources. Effectively, the maintenance of such a dye laser involves the maintenance of two lasers, and this also renders it unreasonable pricewise.

One of the solutions to this disadvantage was conceived and proposed about twenty five years ago[2-4]. It was suggested that energy obtained by the process of electrochemiluminescence (ECL) can be used as a pump for such dye lasers. Efforts were made to realise this idea, but the maximum energy generated was two orders of magnitude lower than the threshold. Recently, Hirouchi *et al.*[1] succeeded in building a device which enhances the efficiency of ECL leading to observation of laser action.

When the anion and cation radicals of a species react with each other, the electron transfer between them excites the atom that absorbs the electron. The energy carried off by the electron is equal to the energy that is expended in creating the two radicals. The excited atom then decays by radiating this energy as light. This is called chemiluminescence. If the radicals are electrochemically generated, that is, under the influence of an electric field, the process is called electrochemiluminescence. Clearly, it is the energy of the electric field that is converted into light energy.

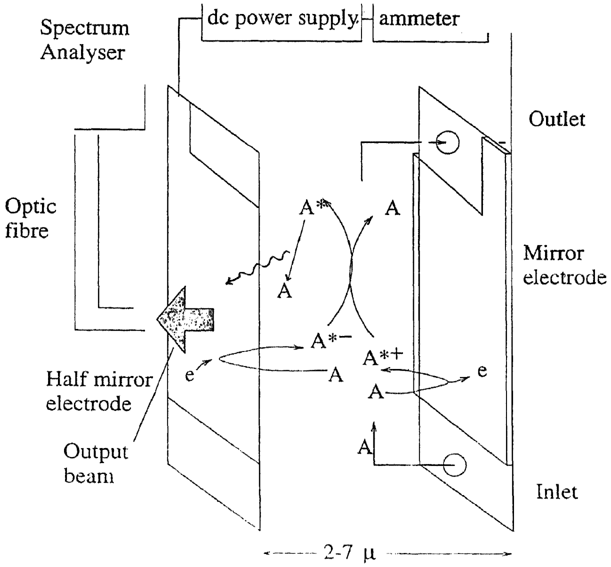

Figure 1. The dye is allowed to flow between the electrodes. The schematic of the chemical reaction is shown in the figure. *A*, A^{*}, A^{*-} and A^{*+} stand for the ground state, excited state, anion radical and cation radical states of the dye molecule respectively.

The dye used in the experiment of Hirouchi *et al.*[1] was Diphenylanthracene (DPA) dissolved in Dimethylformamide (DMF). This dye, when used as a lasing medium, is pumped by a nitrogen laser[5]. The oxidation potential of the molecule of this dye is 1.3 V and the reduction potential is –1.7 V. Both these numbers are with reference to Ag/AgCl. The energy given out when the two radicals combine is equal to the potential difference, which is 3 V. The wavelength corresponding to this energy is ~400 nm, that lies in the blue region of the spectrum. The dye molecules can absorb this energy and fluoresce.

A special cell was engineered to drive the chemiluminescent reaction (Figure 1). A thin layer of platinum was deposited on two quartz substrates (each of area 2 mm × 2 mm). The thickness of the deposition was such that one of them was totally reflecting, and the other had 99.2% reflectance. These two substrates formed the opposite faces of a rectangular cell. The separation between the two faces was about 2–7 microns. The platinum layers also acted as electrodes. The dye was allowed to flow through this cell, and an optical fibre was placed outside the semireflecting mirror to collect the light generated.

The electric field electrolysed the ground state molecules into anion and cation radicals. These radicals released energy in the form of fluorescent radiation on recombination according to the fluorescence spectrum of the dye. The spectrum peaked at 445 nm. Moreover, the fluorescence showed some special features.

The fluorescence spectrum of the dye was seen to be modulated by thin sharp equidistant peaks, which were detected to be the Fabry Perot resonances of the cavity formed by the two mirrors. These resonances occur when light is repeatedly reflected between two parallel mirrors, and the separation between the two mirrors enables certain wavelengths to interfere constructively, resulting in intense lines at corresponding wavelengths.

The dependence of ECL on the current was examined. The intensity of the peaks in the fluorescence spectrum, was measured at different current values in a steady state. Theoretically, the ECL intensity should be proportional to the square of the current. However, the observed intensity could not be represented as a quadratic function of the current. Initially, the intensity showed a very gradual increase with current, up to about 0.45 mA. After that, it grew rapidly with current, showing a clear threshold at 0.45 mA. This dependence of intensity on current is similar to the one observed in semiconductor lasers. An empirical relation was used to estimate the threshold current to be 0.41 mA for the cell, which fairly matched with the experimental value of 0.45 mA.

Two spectra were obtained at two different current values, one above the threshold and the other below the threshold. The peak positions were almost the same for the two spectra, however, the peak heights of the spectrum above threshold were much greater than those below threshold, and the envelope of the spectrum above threshold narrowed. This envelope narrowing effect is similar to that observed in ordinary lasers. This happens because the peaked wavelength starts growing in intensity at the cost of other wavelengths, which are consequently suppressed. This narrowing, called 'line narrowing' is a clear indicator of laser action.

These observations confirm that the emission from the cell was indeed a 'laser', driven by an electrochemical reaction. Thus, ECL can prove to be an easier alternative to pump continuous wave dye lasers in the near future.

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DNA structure: Yet another avatar?

Manju Bansal

Everytime the story of DNA structure seems to reach a conclusion, it bounces back to centre stage by appearing in yet another incarnation. The latest avatar to manifest itself is a stretched and overwound form of DNA reported recently by a French group[1], working with single DNA molecules. When a moderately large stretching force (of about 3 pico Newtons) is applied, the DNA molecule apparently becomes highly twisted and extended, but even more amazingly it takes up an 'inside-out structure' in which the phosphodiester chain is on the inside and the bases are exposed (Figure 1 *a*). Precisely such a structure was proposed in 1953 by Pauling and Corey[2] (albeit with three strands), making use of 'the general principles of molecular structure', which they had applied with such spectacular success in predicting the α-helix and β-structure for proteins[3]. While they were convinced that the DNA structure was a helix, they did not make use of the already available chemical data of Chargaff, which demonstrated that although the base composition of DNA varies widely, certain bases were always present in equal numbers (viz. Adenine = Thymine and Guanine = Cytosine), clearly suggesting some kind of pairing between the bases. So in their model building studies, when they considered the question of arranging more than one chain about the helix axis, they made the wrong choice. As shown schematically in Figure 2, the helix axis can be located either to the left or to the right of the polynucleotide backbone. An axis to the right of the chain, as shown in the top right of Figure 2, results in a structure with phosphates near the helix axis and the bases farther away from the axis and 'fanning' out. Watson and Crick on the other hand placed the helix axis on on the left side of the chain, resulting in the arrangement shown in the top left of Figure 2, with the phosphates on the outside and the bases inside. This arrangement for a two chain molecule readily explains Chargaff's data, if a specific base–base interaction is postulated between the bases A and T, as also between G and C. The two chains can be either parallel or antiparallel to each other. The antiparallel arrangement was chosen, rather arbitrarily, since it was consistent with the psuedo-two-fold symmetry of the basepairs, but has subsequently been confirmed by biochemical studies. Thus, the canonical Watson–Crick structure for hydrated DNA, which gives the B-form X-ray fibre pattern, a two-strand right-handed helix, with ten planar A:T or G:C basepairs of nearly equivalent shape and size arranged in a spiral arrangement, almost perpendicular to the fibre axis, came into existence[4]. The currently accepted detailed structure[5] for the B-form of DNA retains the essential features of the original Watson–Crick model and is shown in Figure 1 *b*. Since this structure was observed when the molecule was fully hydrated and it also immediately suggested a possible copying mechanism for the genetic material and the semiconservative replication of DNA, it was readily accepted as being the 'biologically relevant structure' for DNA. This corollory was repeatedly emphasized, since even before the structure of DNA was known, X-ray fibre diffraction and spectroscopic data had clearly shown that it is quite a pliable molecule, readily undergoing interconversion between various forms (arbitrarily classified as A, B, C, etc.) when ionic or humidity conditions are changed. All these related structures were considered as relatively unimportant minor variants, or distorted versions, of the B-form, which occupied the centre-stage for nearly a quarter century after it was first proposed.

Once the Watson–Crick model for DNA became an accepted fact, the double helix came to be regarded merely as a safe storage device for the genetic information encoded in the nucleotide sequence, that could only be accessed after unwinding of the helix. Hence the double stranded DNA molecule was treated as being a very stable, intrinsi-

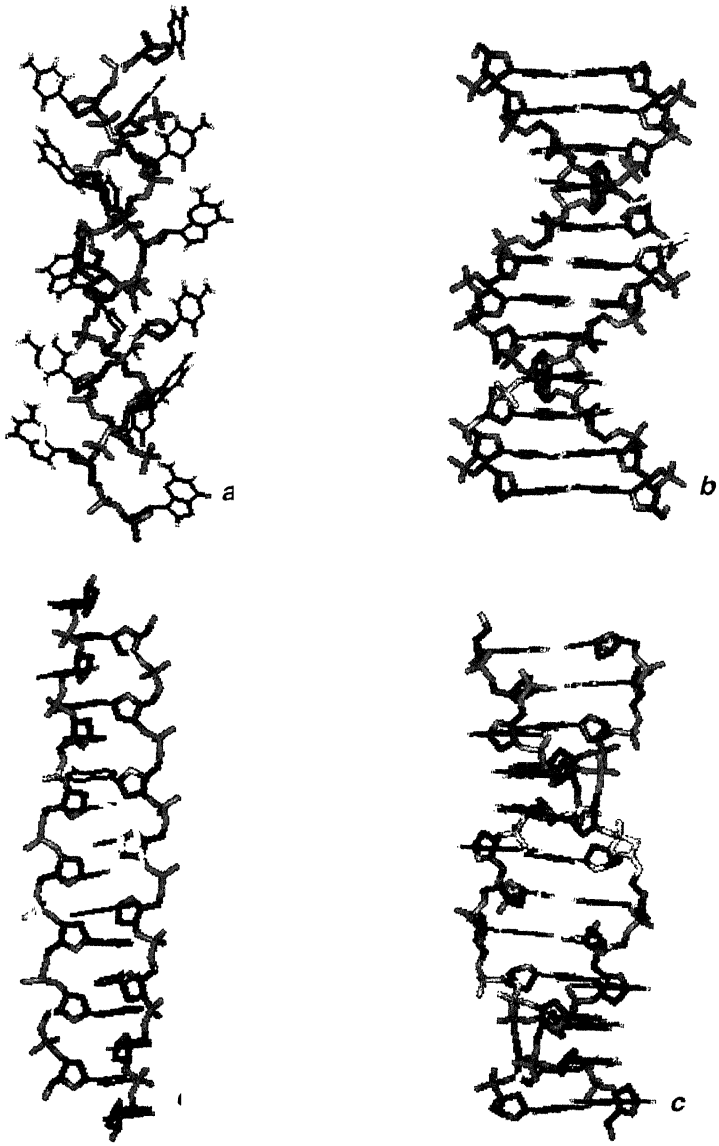

Figure 1. Line diagrams showing four different two-stranded structures for DNA. ***a***, The Pauling-like anti-parallel duplex structure (P-DNA) with phosphate backbone in the centre and bases exposed on the outside; ***b***, The canonical, Watson–Crick B-DNA structure, which apparently undergoes transformation to P-DNA, on stretching without writhing; ***c***, Z-DNA, a left-handed zig-zag structure, which has been observed for alternating purine–pyrimidine sequences, under conditions of high salt; ***d***, An alternative model to P-DNA, which has also been proposed as a structure for the single-stranded circular DNA in the Pf1 filamentous phage, with bases being in the centre and intercalated. A 12-mer fragment of basepaired duplex DNA is shown for B and Z DNA structures (Figures ***b*** and ***c***) while an 8-mer fragment is shown for the two stretched structures (Figures ***a*** and ***d***).

cally uniform entity, requiring strong interaction with proteins or some other ligand, in order to undergo any structural change in the cellular environment. This cozy 'uniform B-DNA centric' world received a severe jolt, with the arrival on the scene of single crystal X-ray structures of DNA oligomers. A dramatic sequence-dependent structural microheterogeneity was observed in the crystal structures of DNA oligomers, with the alternating sequences TATA (ref. 6) and (CG)$_3$ (ref. 7). The latter, in particular, had only the Watson–Crick G:C basepairs as a common feature with the B-DNA structure, otherwise it was completely different – first of all, it had a left-handed helical twist and secondly, it had quite different values for the torsion angles, defining the orientation about the various single bonds, in the guanine and cytosine nucleotides. This gives the phophodiester backbone a distinctly zig-zag appearance (Figure 1 *c*) and led to the structure being dubbed the Z-form DNA. This structure was solved using very high resolution X-ray data, so it could not be ignored, which was the fate of many theoretically model-built structures, but since it was only observed under conditions of high salt, its biological relevance remained questionable and it has also been relegated to the domain of 'interesting curiosities'. However, its formation may be facilitated under the stimulus of torsional stress induced by negative supercoiling.

The faith in the ubiquitous nature of B-DNA was restored when the next crystal structure[8], for a 12-mer fragment, turned out to be very similar to the fibre B-form, even though it had alternating CGCG sequences, flanking an AATT tetramer at both ends. However, a closer look at this structure opened another Pandora's box, since it showed considerable local variability at each dinucleotide step and appeared to be slightly curved overall. This and subsequent oligonucleotide crystal structures have clearly blasted the myth of 'uniform B-DNA' structure and in-fact sequence-dependent variability is now routinely invoked to explain phenomena as diverse as intrinsic bending in mini-circles of kinetoplast DNA, to recognition of promoter regions and replication origins in genomic DNA, by polymerases. It has now become common to talk about A, B or C type dinucleotide steps rather than assigning a particular type to the whole structure!

The next development in the DNA structure story came with the availability of large genomic sequences. These

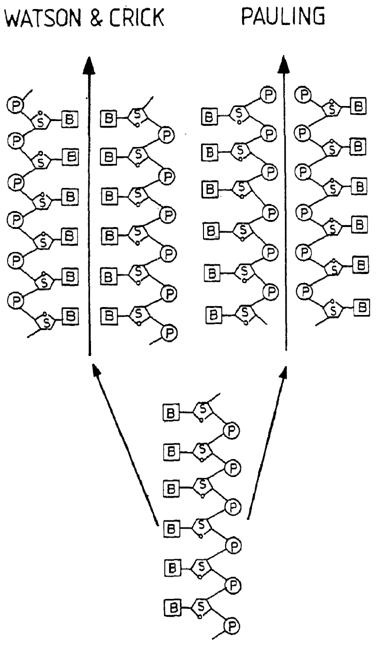

Figure 2. A schematic diagram showing two possible arrangements of polynucleotide chains about a common helix axis. The symbols B, S and P represent the bases, sugars and phosphates, respectively. In the scheme proposed by Pauling, the sugar phosphate backbone occurs inside and a third chain (not shown here) was also present, thus forming a triple-helical structure. In the recently proposed P-DNA, only two chains are involved and each of the chains is highly stretched. In the Watson–Crick scheme also two chains are present, but the bases occur on the inside and can be involved in inter-chain hydrogen bonds.

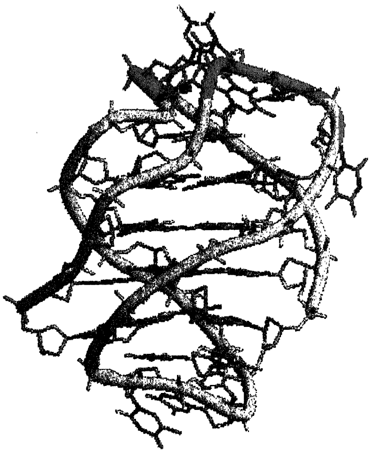

Figure 3. A four-stranded quadruplex structure, stabilized by hydrogen-bonded guanine tetrads, can be formed by a DNA fragment containing guanine stretches, interspersed with thymine and adenine bases which facilitate the chain folding back on itself. Such sequences are found, as single-strand overhangs, at the ends of eukaryotic chromosomes and are expected to take up this type of compact structure, which could seal and thus prevent degradation, as well as fusion of the chromosome ends. The red ribbon highlights the path traced by the phosphodiester backbone.

indicated the presence of several repeat motifs, with sequences which had earlier been shown to take up a variety of unusual structures, for example a single chain helix for poly (C), three chain or triplex structure for [poly (A) + poly 2(U)] and a parallel four chain assembly or quadruplex structure for poly (G). One by one, they have all come out of the cold-storage and found their rightful place in the pantheon of DNA structures. A variant of the G-quadruplex structure, formed by a single guanine-rich fragment folding on itself (Figure 3) has, in particular, evoked great interest since it has been postulated to occur in the telomeric regions at the ends of chromosomes and effectively seal the ends[9]. Also the loss of these regions during successive replication cycle is attributed as the primary cause for 'ageing'. Retain the telomeres and remain 'young forever' seems to be the current thinking.

To return to the beginning, the Pauling-like structure with exposed bases (currently termed as P-DNA)[1] for a highly stretched and overwound form of DNA, with rise per residue along the helix axis of about 5.85 Å and 2.62 units per turn, as compared to 3.4 Å rise and 10 units per turn for B-DNA, had also been proposed as a model for a circular single-stranded DNA in the Pf1 filamentous phage[10]. An alternative structure for this DNA[11], packaged inside the virus protein coat, is shown in Figure 1 *d*. In this structure the phosphate backbone remains on the outside, with its negative charge being neutralized by the basic groups in the coat protein assembly, but the bases in the two antiparallel strands are merely intercalated, rather than basepaired through hydrogen bonds, as in the complementary Watson–Crick double helix.

Thus, while the basic principles and essential structural elements for protein structure, elucidated during the early 1950s, viz. the α-helix and β-structure from Pauling's group[3] and the coiled-coil triple-helical structure for collagen from Ramachandran's laboratory[12] have remained virtually unchanged and unchallenged even today, with only their permutations, combinations and linking regions varying, in the more than 300 unique sequence protein structures currently known, the structure for a single DNA molecule seems to be able to adapt itself to its environment by twisting, turning and stretching into completely different 'avatars'. The last word in the DNA story has probably still to be written, but in the meantime Linus Pauling, whose biggest disappointment was that he did not discover 'the DNA structure', can now rest in peace, his structure has at last found a niche in the pantheon of DNA structures!!

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OPINION

Lest we forget

S. R. Valluri

The immediate reaction of many Indian scientists and technologists after the recent nuclear explosions was a sense of euphoria, that they could obtain notable successes whenever the government supported them. Detached introspection by many however raised serious doubts about these developments against the historical background and potential future consequences. Realization dawns that the compulsions of the politicians and some scientists to exercise such options, will have to be moderated in the present day world. They can lead to dangerous situations to humanity at large, apart from creating for ourselves avoidable and adverse situations in the virtually unipolar world in which we now live. We do not seem to have any leverage or any viable moves to play in the chess game of world politics.

It may not be easy the first time, but history demonstrates that while it is not simple, it is not as difficult the second or the third time to achieve such objectives, given the political will, economic backing, and a reasonable degree of capability. Therefore, whenever we scientists and technologies propose development of weapons of mass destruction and their delivery systems, we will do well to think of the implications. Our actions can have profound consequences for humanity at large.

Nuclear power can certainly be used for peaceful purposes, such as generation of electricity. In fact, considering our limited fossil fuel resources, we seem to desperately need it. But nuclear weapons are tools of mass destruction and their development and deployment is altogether a different affair. It was apparently the possibility for peaceful uses of nuclear explosions (PNE), that prompted India to look into the development of nuclear explosive devices. However, the line that separates the development of devices for peaceful purposes from those intended for not so peaceful purposes, such as weapons of mass destruction, is thin indeed. Our priorities in the development of these devices are now obviously for producing weapons of mass destruction.

The first ever test of a nuclear bomb 'Trinity' took place on 16 July 1945 in New Mexico. The programme got started as a result of a letter from Einstein to Roosevelt, due to the initiative from the Hungarian scientist, Szilard. The war in Europe was over by then. The US dropped one bomb on Hiroshima on 6 August 1945 killing 140,000 people in one stroke and eventually 200,000 in all, out of a total population of 400,000. In Nagasaki, 70,000 people died directly and 140,000 people in all, out of a total population of 250,000. 'Of the 76,000 buildings in Hiroshima, 70,000 were damaged or destroyed, 40,000 totally'. 'It is no exaggeration to say' reports a Japanese study 'that the whole city was ruined instantaneously'. Comment of a child who witnessed the explosion and survived: 'The river became not a stream of flowing water but rather a stream of drifting dead bodies. No matter how much I exaggerate the stories of the burnt people who died shrieking and how the city of Hiroshima was burnt to the ground, the facts would still be clearly more terrible' (Richard Rhodes, *The Making of the Atomic Bomb*, Simon Schuster, 1986). It need not be stressed that they were the bodies of innocent people. These are inconvenient facts to face.

One would imagine that in the name of developing deterrence, we too have achieved the ability for such destruction. Our scientists and technologists who have developed the bombs do not seem to have personally realized the enormity and the consequences of their actions, presumably because our tests were conducted underground. Bainbridge, the above ground 'Trinity' test director said immediately after the explosion to Robert Oppenheimer, the scientist who was responsible for the whole programme 'now we are all sons of bitches'. Oppenheimer, put it more succinctly. He recalled a line from Bhagavad-Gita, 'Now I am become death, the destroyer of the world' (*ibid.*)

Szilard and several others, tried to get the tests and use of the bombs in war against Japan, and their proliferation, stopped by having a letter written by Einstein to President Truman. They argued that it would precipitate a race between the US and the USSR for production of these devices. By then, the politicians got hold of the issue, with the scientists taking the back seat about its field use. From the estimated 12 to 15 kiloton 'Trinity' bomb, they graduated to megaton hydrogen bombs, capable of destroying whole cities and civilizations and stockpiled them in tens of thousands. The Strategic Arms Limitation Treaty (SALT), CTBT, and the Nuclear Nonproliferation Treaty (NPT) are asymmetric efforts to control the spread of the nuclear arms race. They are designed to protect the interests of the major nuclear powers, while preventing others from joining the race, thus instinctively forcing others who also have the capability, to join the nuclear club.

It was apparently the testing of a nuclear device on 16 October 1964, by China that started the debate about the development of the 'Peaceful Nuclear Explosives' in India. China's test of a thermonuclear device in June 1967, triggered off the nuclear design of an explosive in Bhabha Atomic Research Centre (BARC). Meanwhile, differing views continued to be heard on nuclear weapons option for India. Sarabhai, who took over as Chairman, AEC and Maj. Gen. Som, then Director of the Institute of Defence Studies and Analysis (IDSA) apparently felt that nuclear weapons were not needed. Some people like K. Subramaniam the then new Director of IDSA, have been arguing for it and some others like Gen. Kariappa against it (*The Atomic Energy in India*, 50 years, Publications Division, DAE, Government of India). It would appear that it was the anxiety of the nuclear and defence scientists to establish their credentials and the political perceptions that have guided our policies since then. It was reported that both the prime ministers, P. V. Narasimha Rao and H. D. Deve Gowda were also apparently approached for their consent for the testing of the nuclear devices, but they had refused. However, development of nuclear deterrence has been a part of the BJP manifesto. It gave its consent to the scientists shortly after it came to power.

It is clear that our scientists achieved a quantum jump in the nation's ability to create weapons of mass destruction. But at what price? One wonders if really 'Buddha smiled', to quote the ironical code phrase used to inform the Prime Minister after the first successful nuclear explosion in Pokhran in 1974. The code phrase would seem to display a certain cynical contempt for the value systems Buddha espoused. These recent developments should make us ponder over the potential consequences of our current compulsions for our dance of death and destruction.

The few senior scientists in India who have spoken since last May, would seem to be more concerned about the constraints on their work following the US sanctions than on the potential dangers to humanity they imply. It is sad that an opportunity for a momentous national debate has been reduced to the level of protecting personal interests.

The question arises, at what price? Who are our adversaries and what are our relative strengths for a nuclear race and confrontation? Few knowledgeable people believe that it will be wise for us to wage even a full-fledged conventional war with China, leave alone a nuclear war. What with their estimated 450 nuclear warheads, compared to an estimated 65 with us (*India Today*, 1 June 1998), it does not make sense to join the race, unless we wish to bankrupt and destroy ourselves in the bargain. Rammanohar Reddy (*The Hindu*, 31 August, 1, 2 September 1998) estimated that to exercise a meaningful nuclear option, after taking into account the former army chief General Sunderji's estimated requirement of 150 warheads and associated delivery systems, we need about Rs 28,000 crores (about US $70 billion) of investment. Lest we forget, we may remind ourselves of the estimates given by P. V. Narasimha Rao, the then Cabinet Minister for HRD, for setting up the Navodaya School System. It was also about Rs 28,000 crores. He had to drop the idea, as such funds were just not available. Recently, M. M. Joshi, the HRD Minister expressed his inability to provide school education to all the children as the government did not have the Rs 40,000 crores needed to implement it. One wonders which is more important for the nation: producing nuclear warheads and delivery systems that the government claims are needed, only as a deterrent and not for first use, or education of thousands of children; or for that matter, use of such funds to build up the infrastructure of the utterly inadequate university and research system, so that they could form the backbone of the industrial base of the country, with associated amplification of benefits.

Thrice before, in wars with Pakistan, we have won. We did not need nuclear weapons to defend ourselves against them. But when we exploded the nuclear bomb in 1974, we changed the situation drastically. Pakistan demonstrated its capability shortly after our explosions last May. Ours seemed almost as if they were intended to call Pakistan's 'bluff' about their capability. It turned out, that they too developed them and altered the balance of power in the subcontinent, when we clearly had superiority in conventional weapons, recognized even by Pakistan.

If we have the courage to be honest with ourselves, we have to admit, that it was we who started the nuclear arms race in our subcontinent. Why should we be surprised if China helped Pakistan, considering the adage, 'any enemy of my enemy, is my friend'?' It has been stated by the minister for External Affairs that in any case Pakistan was developing nuclear weapons and getting ready to explode them even before we started our recent exercise. May be so. We should then have waited and let Pakistan explode their weapons first. We demonstrated our capability in 1974 itself. One could assume that work was going on in BARC to refine the technology to build better bombs. But should we have invited the stigma of being the first to reignite the dormant nuclear fire in the subcontinent?

In any case, it is no longer clear what we should do with our nuclear stockpile, such as it is. Whether it is the currently estimated 65 warheads or General Sunderji's minimum of 150 for deterrence capability, the question arises: 'what do we do after these are exhausted'? If it is a war with China, we will presumably retaliate with our 150 warheads, after China launches theirs on first use, with 300 still remaining in their stock. Should we then in anticipation, mount a crash programme now itself to close the gap to have our 450 warheads to match theirs, and keep on producing more to keep up with them and bankrupt ourselves in the bargain? Such a nuclear race will be utter madness both militarily and economically.

If on the other hand, it is argued that our deterrence capability is only to meet a challenge from Pakistan, the roles will be reversed with Pakistan trying to catch up with us in a nuclear race.

The only silver lining in this whole affair, such as it is, is that neither Pakistan nor India can now afford to start even a conventional war, for fear that it may escalate into a nuclear holocaust by error of judgment, with disastrous consequences for both. But sooner or later, the two countries will have to give up their present inflexible and untenable stands and negotiate in good faith, in a spirit of give and take.

If the big five want a commitment from India and Pakistan to sign CTBT, NPT, etc. the least that they could obtain is an unambiguous guarantee that such a commitment will not expose them to a nuclear ransom/attack.

Even if it is signed, CTBT does not stop us from making the bombs. It only says we cannot test them. But this is not the real issue. We should voluntarily refrain from stockpiling the bombs. It is a losing proposition. We should continue to press for universal nuclear disarmament.

The US was undoubtedly churlish in imposing sanctions on India and Pakistan. When an earlier (Reagan) US administration indulged in such an exercise, Indian scientists and technologists had achieved some extraordinary breakthroughs in critical technologies that were of vital interest to us. We should look upon this US decision as a blessing in disguise and an opportunity to bridge technology gaps, not for preparing to wage wars of mass destruction, but for improving our lot, and not complain about denial of equipment or being treated as second class citizens among the western scientific community. There would be enough challenging tasks, if our work also is inspired by our own societal requirements.

If we want to be listened to politically, we have to be either morally or militarily or economically strong. The day Gandhiji, the apostle of peace and nonviolence was assassinated by Godse, we lost the right to wear the mantle of moral righteousness, and assume the stance of the keepers of the conscience of the civilized world. Military strength has no meaning if we are not economically strong, as it cannot be sustained in the long run. Common sense dictates that our priorities cannot call for making more bombs, given our poor economic base and neglected infrastructure, with poor energy supplies, poor roads, poor telephone services, poor transportation systems, poor water supply, poor health and family planning systems, poor sanitation and poor educational and research bases. Establishing such infrastructure only will enable us to transform ourselves into a developed country.

In all these, we the scientists and technologist have an important role to play. One would suspect that to win the argument, the DAE scientists have used the so-called need to confirm their ability for building bombs to demonstrate our deterrence capability. Lest we forget, we should remember, we have started the nuclear race in the subcontinent. In this, our scientists were supported by the politicians for its obvious 'political mileage' such as it is. The power to destroy whole civilizations has been given into the hands of the politicians. We cannot any longer say, 'we are not responsible for what the politicians would do with these tools of mass destruction we are providing them'. If the politicians say, it is only a deterrent and they do not propose to exercise the option of first use, the question arises: 'how much deterrence is deterrence?' Enough to have the potential to bankrupt ourselves and divert funds that are more urgently needed in other areas? The External Affairs Minister was recently reported to have stated that a number cannot be assigned to it. This is precisely the problem. Does the government seriously think that we have the wherewithal for indulging in the nuclear race and respond to all these above requirements? It would be an utter and absurd distortion of national priorities, if it were to be so.

It has become clear for quite sometime, that in the contemporary world, nuclear war as an extension of foreign policy to resolve issues, has become irrelevant. We should examine very carefully this compulsion of ours to join the nuclear club. The S&T community has a moral obligation to educate the society and the nation. The situation has become too dangerous to be left exclusively to politicians and a few 'establishment scientists' cloaked in secrecy, to determine our destinies.

In his State of the Union address before laying down his office, President Truman, the man responsible for dropping of the nuclear bombs on Hiroshima and Nagasaki, belatedly realized from his personal involvement, the horrors that can be let loose. He stated, 'the war of the future would be one in which man could extinguish millions of lives at one blow, demolish great cities of the world, wipe out the cultural achievements of the past – and destroy the very structure of a civilization that has been slowly and painfully built up through hundreds of generations. Such a war is not a possible policy for rational men'. In his foreword to the book by the first Scientific Adviser to the Minister of Defence of the Government of India on *Nuclear Explosions* ('56 and '58 editions, Publications Division, Government of India), India's first Prime Minister Jawaharlal Nehru had this to say: 'Enough is known, however, to give us some kind of a picture of a war in which these weapons are used. War is associated with death...'. 'We have now to face death on a colossal scale and what is much worse, the genetic effects of these explosions on present and future generations. Before this prospect, the other problems that face us in this world become relatively unimportant...'. 'These conclusions (of Kothari) expressed in restrained scientific phraseology, tell us of the fate in store for us if we are not wise enough in time to put an end to this horror'. Nehru said this four decades ago. Is this the scenario for which we should prepare ourselves and is this the club, India wishes to join as an active partner?

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A protein folding and RNA transport based model for eukaryotic gene regulation

Nascent polypeptide folding[1] and RNA trafficking[2] are areas of great significance in cell function. Here I present a hypothetical eukaryotic gene regulatory mechanism where the two cellular activities interact with each other through molecular chaperones and bring about translational regulation. Although a theoretical consideration, most of the steps involved are known cellular events.

From transcription of mRNA in the nucleus to its subsequent translation in the cytoplasm, the process of gene expression requires concerted and coordinated activities of a host of molecular machines. It is tempting to speculate that if the growing polypeptide chain is somehow able to communicate with the translating mRNA, the message so generated at the site of translation would have the potential to flow in the reverse direction to the site of transcription; this can add to the cells' repertoire of gene regulatory mechanisms.

The sequence of events in this model would be more or less like this: accumulation of large amounts of protein beyond a certain threshold level (protein crowding) → nascent polypeptide destabilization → molecular chaperone–nascent polypeptide–RNA transporting (localizing) protein [RT(L)P] interaction → mRNA masking accompanied by translational inhibition and RT(L)P tethering → failure of RT(L)P nucleocytoplasmic shuttling → inhibition of fresh nuclear mRNA export → inhibition of pre-mRNA processing → inhibition of mRNA turnover from the site of transcription → inhibition of transcription.

Once the excess protein turns over from the site of translation, the following feedback may ensue: protein uncrowding → loss of molecular chaperone–nascent polypeptide–RT(L)P interaction → mRNA unmasking → resumption of translation and availability of RT(L)P for fresh nuclear mRNA export resulting in normal pre-mRNA processing, and mRNA turnover from transcriptional site would then resume and the gene in question would start transcribing.

The autoregulatory model described above is based on the premise that masking a partially translated mRNA from further translation would inhibit its further localization in cytoplasm, thereby affecting its transport, processing, turnover from transcriptional site and synthesis of RNA in the nucleus, in that order. Likewise, mRNA unmasking would help resume the information flow from DNA to RNA to polypeptide. The specificity of RT(L)P in transcript localization would, of course, be important in this model. In other words, the above model requires the mRNA to be asymmetrically localized, and is therefore a model for mRNA-specific translational regulation. However, the same model when involves general RNA transporting, not mRNA-specific localizing, factor(s) could however also serve for a general translational regulation as described below.

During heat-shock (stress) response expression of normal (non heat shock) genes is regulated in such a way that onset of heat shock results in inhibition of their transcription as well as translation, and once the stress period is over, the normal synthetic activities of RNA as well as of proteins are resumed. It is possible that expression of some of the normal genes is regulated according to the above model, i.e. the stress would result in the destabilization of nascent polypeptides and the rest of the negative-feedback pathway would then follow, resulting in translational as well as transcriptional inhibition. Once the stress is discontinued, the molecular chaperones will dissociate from the complex, resulting in resumption of normal synthetic activities. Thus, for the heat shock model to work, the nascent polypeptide to molecular chaperone ratio might be important.

The hypothetical autoregulatory model described above is simple and accommodative of alternative views. Gene expression can be regulated at transcriptional, post-transcriptional, translational, and post-translational levels. The present model has the potential for regulation at all such levels, transcription, pre-mRNA processing, RNA turnover from the site of transcription, nuclear RNA export, cytoplasmic RNA accumulation, translation and protein turnover. However, the common requirement for regulation at all these levels is the nascent polypeptide – molecular chaperone – RT(L)P interaction.

Protein crowding, heat shock and several other stress conditions are known to result in protein destabilization (aggregation, unfolding and misfolding)[3]. Co-operation of translational machinery and heat-shock proteins in protein synthesis[4–6] as well as the involvement of molecular chaperones in nascent polypeptide stabilization[1,3] are well-documented events. Molecular chaperones, which include heat-shock proteins, are a class of proteins that mediate protein–protein interaction and participate in diverse activities such as synthesis, folding assembly, disassembly, translocation, and degradation of proteins[7,8]. Similarly, heat shock proteins are also believed to interact with mRNA and play a role in their protection, localization, transport and degradation[9–16]. They are also known to bind actin filaments[17], a part of cytoskeleton known to participate in RNA transport. Keeping the above in view, it is perhaps not unreasonable to think of some kind of molecular chaperone–RT(L)P interaction.

The protein-crowding model assumes that various mRNAs involved in such regulation are asymmetrically localized in the cytoplasm and that their exact localization requires specific localizing protein/factor(s). The accumulation of particular mRNAs at specific sites in the cytoplasm is now believed to be a general phenomenon occurring in all polarized cell types. Other than germ cells and early embryos, it also occurs in a host of somatic cell types, including muscle, epithelia, fibroblasts, neurons, oligodendrocytes etc.[2,9,18–20]. The evidence that transcripts are localized by vectorial export from the nucleus[18] further supports the model. In addition, the known involvement of cytoskeleton in RNA localization/transport[2,9,18–22] and the association of mRNA-cytoskeleton complex with translational machinery[20–23] are in consonance with the proposed model. The 3′ untranslated region (UTR) of the mRNA is known to function in RNA transport/localization[2,19–21,24,25]. This evidence, in conjunction with others that 3′ UTR-binding proteins associate with polyribosomes[26], that 3′ UTR can regulate translation[2,27,28], and that 3′ UTR-binding proteins display homology with the heat-shock proteins[25] support the present hypothesis.

In order to make the model work, the transcribed RNA must associate with some protein(s) first and then be transported to the site of translation. Further, the protein involved must also be able to go back to the transcription site, pick up another RNA molecule and come back again to the site of translation. And the cycle should go on. That such events indeed occur have now become increasingly clear[2,29–31] by co-transcriptional binding of heterogeneous ribonucleoprotein particles (hnRNPs) and various other proteins to 3′ UTR and the role of these proteins in transport of RNA from the site of transcription to that of translation. Moreover, it is also known that the RNA-transporting proteins shuttle between the transcription sites of RNA and the sites of protein synthesis[2,32–35].

The model also assumes that alteration in RNA turnover from the site of synthesis would affect pre-mRNA processing which, in turn, would influence transcription. Nucleus is highly organized and dynamic with respect to functions of gene transcription, pre-mRNA processing, RNA turnover from transcriptional site and nuclear RNA export. Co-transcriptional pre-mRNA processing as well as coupled RNA turnover: pre-mRNA processing are all known events[36–38]. Not only that, RNA polymerase II has also been shown to be involved in mRNA processing[39,40]. All these, along with the existence of a communication system between RNA polymerase II and 3′ UTR processing factors integrating different nuclear processes, are in agreement with the proposed model.

The present hypothesis describes a gene-regulatory mechanism by which translational inhibition and activation can bring about repression and induction, respectively, of RNA localization, nuclear export, turnover, processing and transcription in the given order. The focal point in this regulatory pathway is the unmasking of mRNA, i.e. formation of nascent polypeptide–molecular chaperone–RT(L)P complex to transiently sequester RNA into translationally inert ribonucleoprotein (mRNP) particles. Several examples of 3′ UTR-based and transacting-factor-mediated translational regulation in metabolic and developmental control are known[41–44]. The feature which is unique in the model proposed here, is the involvement of molecular chaperones. As molecular chaperones are ubiquitous proteins occurring constitutively, developmentally as well as under stress conditions, the model can possibly serve for global gene regulation. In addition, owing to the involvement of 3′ UTR in the regulatory pathways, the model also has the advantage of being applicable to transcriptional regulation. 3′ UTR can be mRNA specific, and thus capable of spatially controlling translation.

While in the heat shock model, the normal mRNA and protein synthetic activities are inhibited due to a general unavailability of RNA transporters, the protein-crowding model provides an autogenous regulatory pathway where excess protein inhibits further synthesis of RNA due to a shortage of poly(A)$^+$ RNA-specific localizing factor(s). In case of threonyl-tRNA synthase, the protein binds to its own mRNA. This binding competes with that of the ribosome and thus inhibits translation initiation[45]. Similarly, thymidylate synthase also binds to its own mRNA and brings about translational repression[46]. Several other examples of autoregulation, based on direct protein–mRNA interaction, are also known. The autoregulatory mechanism described here, however, envisages a complex interaction among the various proteins and the mRNA.

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Dose-response relationship in the microbial suppression of *Sclerotium rolfsii* by *Trichoderma pseudokoningii*, strain MTCC 3011

Sclerotium rolfsii is a devastating plant pathogen infecting over 500 species of plants[1]. It can infect seeds, seedlings, mature plants in the field, and cause diseases of fresh vegetables and rhizomes while in storage and during transit[2]. In recent years, the biological control as well as the management of this pathogen under field conditions[3], using its antagonistic fungi, *Trichoderma* spp., has emerged as a viable alternative to chemical fungicides. Recently, we have isolated a strain (MTCC 3011) of *T. pseudokoningii* from sclerotium of *S. rolfsii*[4]. This strain was found to be highly effective in suppressing the growth of *S. rolfsii* on ginger rhizome, and on several vegetables (beet, carrot, bitter gourd, elephant-foot yam, etc.) while in storage[4,5]. Under other species of *Trichoderma* (*T. viride*, *T. harzianum*, *T. virens*, *T. koningii*), *T. pseudokoningii* has been rarely reported in literature as a biocontrol agent[6]. Hence, there is a need for a thorough characterization of this species in order to use it as an effective biocontrol agent of plant diseases. In this paper, we report on the effect of the type of inoculum and inoculum density of *T. pseudokoningii* for its efficacy as a microbial-suppressive agent of *S. rolfsii*. We also propose the possible mechanism of biocontrol in this system on the basis of inferences from the present results as well as our previous observations.

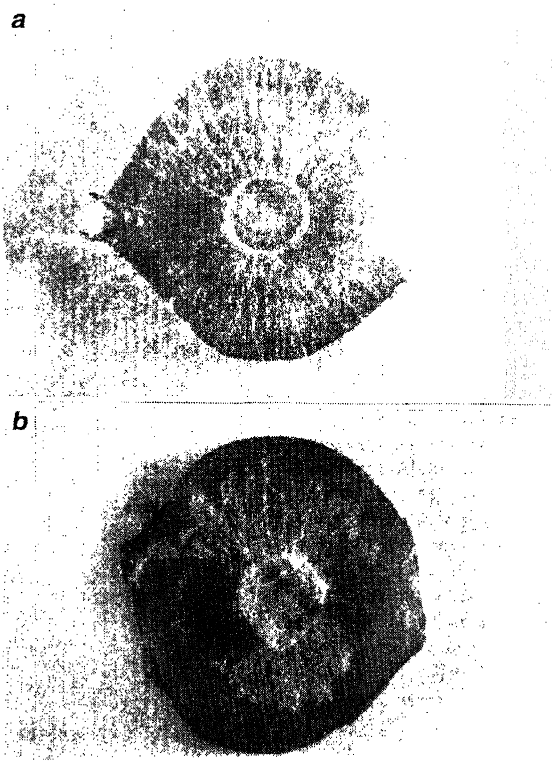

Figure 1. Overgrowth of *T. pseudokoningii* on *S. rolfsii* after 5 days of incubation. ***a***, Growth of *S. rolfsii* on sliced ginger rhizome not inoculated with *T. pseudokoningii*; ***b***, *S. rolfsii* growth being overgrown by *T. pseudokoningii* on sliced ginger rhizome inoculated with *T. pseudokoningii* (0.05 mg ml^{-1} mycelial suspension).

The disease-control potential of *T. pseudokoningii* for *S. rolfsii* was studied using a bioassay described by us earlier[4]. Briefly; one side of sliced ginger

Table 1. Effect of pre-treatment with *T. pseudokoningii* on the mycelial growth of *S. rolfsii* on sliced ginger rhizomes

Type of inocula of *T. pseudokoningii*	Concentration ml^{-1}	Linear growth* of *S. rolfsii* (mm) ± SE 24 h	48 h	72 h	96 h
Mycelial suspension	50 mg	0	0	0	0
	5 mg	2.0 ± 0.6	**	**	**
	0.5 mg	3.3 ± 0.3	4.0 ± 0	**	**
	0.05 mg	7.7 ± 0.3	10.0 ± 1.2	10.0 ± 1.2	**
Conidial suspension	10^8	0	0	0	0
	10^7	2.3 ± 0.3	2.3 ± 0.3	**	**
	10^6	4.7 ± 0.9	4.7 ± 0.9	4.7 ± 0.9	**
	10^5	7.3 ± 0.9	7.3 ± 0.9	7.3 ± 0.9	**
	10^4	8.3 ± 0.7	9.7 ± 0.3	9.7 ± 0.3	**
	10^3	10.3 ± 0.3	19.7 ± 0.3	54.3 ± 1.2	65.0 ± 2.9
Control		11.7 ± 0.9	23.3 ± 2.8	52.7 ± 1.5	69.0 ± 4.6

*Mean of 3 replicates; **Growth of *S. rolfsii* overgrown by *T. pseudokoningii*.

rhizome was dipped in either a conidial inocula (harvested from 7-day-old plate culture) or mycelial inocula (prepared by blending in sterile water, blotted-dry mycelia that was harvested from 4-day-old shake culture) of *T. pseudokoningii*. The excess suspension was drained off, and the rhizome slices, treated side upwards, were placed on 3 layers of filter papers in petri dishes, 9 cm in diameter. The filter papers were moistened with 3 ml sterile water. The slice was then inoculated centrally with mycelial discs, 7 mm in diameter, of *S. rolfsii* cut from the margin of a 3-day-old culture. The plates were incubated at 24–28°C in polyethylene bags lined with moist tissue papers. The linear growth, from the edge of the inoculum disc of *S. rolfsii* was recorded daily.

The data on the biocontrol potential of *T. pseudokoningii* for *S. rolfsii* indicated that both the conidia and mycelia were effective in suppressing the mycelial growth of *S. rolfsii* on ginger rhizomes (Table 1). 50 mg ml^{-1} of mycelial suspension and 10^8 ml^{-1} of conidial suspension completely suppressed the growth of *S. rolfsii*. The ability to suppress *S. rolfsii*, however declined with the reduced inoculum level of *T. pseudokoningii*; 10^3 conidia ml^{-1} was ineffective. At the other concentrations though *S. rolfsii* showed growth initially, however, it failed to grow with time (unlike in the control, where *S. rolfsii* continued to grow (Figure 1 *a*)), and finally was overgrown by the *T. pseudokoningii*, as revealed by the profuse green growth of the antagonist on the pathogen (Figure 1 *b*). Microscopic examination of such growth revealed mycoparasitic coiling of *S. rolfsii* hyphae by *T. pseudokoningii*, and complete lysis. Plating of these growths on media amended with benomyl (to selectively suppress the growth of *T. pseudokoningii*) resulted in no fresh growth of *S. rolfsii*, suggesting killing of *S. rolfsii* by *T. pseudokoningii*.

One of the most significant factors in any effective biocontrol programme is the understanding of the mechanism of biocontrol. For example, in the present study, such information will help in further improving the performance of the antagonist. *S. rolfsii* being a menace mostly of the seeds/standing crops, a good amount of work has been carried out on the mechanism of biocontrol when *Trichoderma* spp. are applied to soil or seeds. In soil-borne infections, both mycelia and sclerotia (resting structures) play an important role in causing infection. Biological control of *S. rolfsii* in soil has been postulated to be due to the parasitism of sclerotia[7]. However, under the post-harvest conditions, the pathogen spreads in the form of mycelia only. Therefore, a post-harvest system forms a unique model to study the ability of the antagonist to suppress the mycelial growth of the pathogen exclusively. Mycelial growth of *S. rolfsii* can effectively be inhibited either through mycoparasitism/enzymatic lysis or antibiosis. Our earlier studies indicated that antibiosis does not play an important role in inhibiting *S. rolfsii* in a post-harvest system[8]. The present study has clearly established the role of mycoparasitism leading to hyphal lysis (presumably through the production of lytic enzymes like chitinases and β-1,3-glucanase) in biological suppression of *S. rolfsii* mycelial growth (Figure 1). The method described here (ginger slice bioassay, at lower dose of the antagonist) could be used as a model of *S. rolfsii in situ*, which would be more reliable than the widely-used dual inoculation technique in culture medium.

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Atypical chronic form of *Aeromonas hydrophila* infection in Indian major carp, *Catla catla*, from Andaman

Intensive and semi-intensive aquaculture with the use of hybrid species, high stocking densities per unit area, feed bio-additives, artificial feed and other improved managemental practices is progressing steadily. With this intensification, the problem of microbes affecting the susceptible hosts already under stress, started posing a threat to the steady progress of aquaculture in many parts. *Aeromonas hydrophila* remains in the center stage so far as Indian major carps are concerned[1]. The disease, due to *A. hydrophila*, was classified[2] under four categories; namely, acute rapidly fatal septicemia showing a few gross symptoms; an acute form showing symptoms of dropsy, blisters, abscesses and scale protrusion; chronic ulcerous form with symptoms of furuncles and abscesses; and latent form with no symptoms. In India, septicemia in Indian major carp, showing an ulcerative form of infection in catla; an acute septicemia in rohu and catla; haemolytic disease in Indian major carps and acute form of dropsy in *Cirrhinus mrigala*, due to *A. hydrophila* have been reported[1,3–6]. In Andaman, during 1996–1998, many sporadic cases of death in mature catla due to a milder and chronic form of a disease with thinning of musculature giving big head appearance, fluid accumulation in the abdomen without haemorrhagic ulcers and erosion of the scales were observed (Figure 1). Even though all the three species of Indian major carps were stocked in the ponds, this atypical infection was exclusively observed in catla fishes. The bacteriological investigation of this chronic form of disease, and comparison of the etiological agent with *A. hydrophila* causing acute dropsy, have been discussed.

The diseased fishes were obtained from farmers during field investigations on the reported death of mature catla fishes. The affected fishes were found to be anorexic, lethargic and were showing characteristic surfacing prior to death without any superficial ulcerative or degenerative changes. A similar report of sporadic deaths of breeder catla fish was also received from the Govt. Freshwater Fish Breeding Farm, Port Blair. On postmortem examination, straw-coloured fluid was found in the abdomen in all the cases. From the moribund fishes, samples were processed from gills, liver, heart, kidney and abdominal fluid for bacteriological investigation. Predominantly cream-coloured, mucoid, round elevated colonies on tryptone soya agar (TSA) and brain heart infusion (BHI) agar and mucoid centrally dark green-coloured colonies with lighter periphery on aeromonas selective (AS) agar were observed, irrespective of source of inoculum. The isolates obtained were characterized by their cultural, morphological, and biochemical characters using standard procedures.

The organisms were gram (–)ve, motile, nonsporulating rods, occurring singly. Based on the comparative biochemical test results (Table 1), the isolates were identified, following the scheme of Holt *et al.*[7], as a strain of *A. hydrophila*, different from highly virulent *A. hydrophila*, the causative agent of acute dropsy reported earlier[6]. The present isolate did not ferment salicin, sucrose and arabinose in contrast to earlier *A. hydrophila* isolate[6]. The observed variation in acid production from different sugars[3,5,8] might be an indication of strain difference between the two isolates. Easy isolation with high percentage recovery of *A. hydrophila* in common laboratory media: like blood agar from ulcerative infection; TSA from acute septicemia; nutrient agar (NA) from haemolytic disease; fish infusion nutrient agar (FINA), TSA and AS agar from acute infectious abdominal dropsy and FINA from epizootic ulcerative syndrome, were reported earlier[3–6,8], as in the present report.

To fulfill Koch's postulate, the pathogenicity test was conducted in catla fish by intraperitoneal inoculation of live

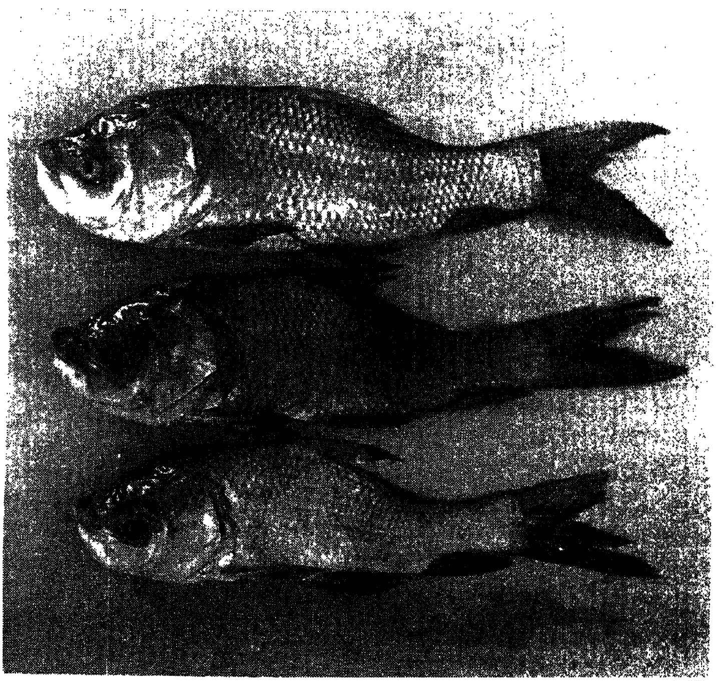

Figure 1. Infected catla fish showing cachectic condition with thinning of the body.

Table 1. Comparison of biochemical characters of standard strains of *A. sobria*, *A. caviae*, *A. hydrophila* (Holt *et al.*), *A. hydrophila*[6] and the present isolate

Tests	*A. sobria*	*A. caviae*	*A. hydrophila*[7]	*A. hydrophila*[6]	Present isolate
Methyl red	–	+	+	+	+
Voges-Proskauer	D	–	+	+	+
Citrate	–	D	D	+	+
H_2S	–	–	+	+	+
Nitrate reduction	–	+	–	+	+
Gas in D-glucose	–	–	+	+	+
Lysine	+	–	D	ND	–
Dnase	–	+	–	+	+
KCN growth	–	+	+	ND	+
Phenylalanine deaminase	+	–	–	–	–
Acid from					
salicin	–	+	+	+	–
Arabinose	–	+	+	+	–
Dextrose	+	+	+	+	+
Maltose	+	+	+	+	+
Sucrose	(*)	+	+	+	–
Trehalose	(*)	+	+	ND	+
Mannitol	–	+	+	+	+
Galactose	+	+	+	+	+
Mannose	+	(*)	(+)	+	+

(+), Most species positive; D, some species positive/some species negative; (*), strains vary; ND, not done.

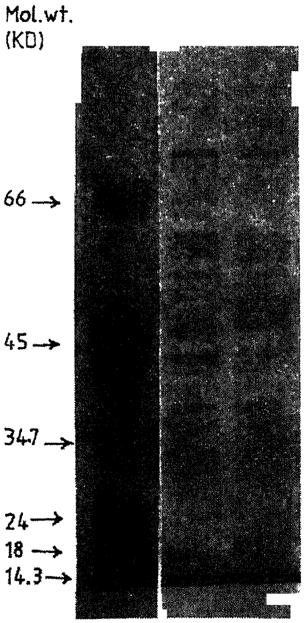

Figure 2. Comparison of polypeptide profiles of *A. hydrophila* isolates in 5–15% gradient SDS gel. M, markers SDS-6 (Sigma); 1, *A. hydrophila*, causative agent of acute dropsy in *C. mrigala*; 2, *A. hydrophila*, causative agent of atypical chronic infection in *C. catla*; → shows the major difference between the two isolates.

A. hydrophila whole-cell suspension at a concentration of 1.5×10^9 CFU/0.2 ml/fish, using PBS as control. No appreciable disease manifestations except rare mild dropsy symptoms, four-days post-inoculation and death in less than 20% experimentally infected fishes after 6–8 days, leaving the rest with no apparent disease symptoms till the 10th day after inoculation. The bacteria could be re-isolated from both the dead and the unaffected experimental fishes. This is in contrast to our earlier report of death of all the experimental fishes within 48 h after intra-peritoneal inoculation of 1.5×10^8 CFU/0.1 ml/fish of *A. hydrophila* isolated from acute infectious dropsy in *C. mrigala*. In other recent comparative virulence studies on six *A. hydrophila* isolates, we found that the dose that was lethal to 50% of test subjects (LD_{50}) ranged from $1 \times 10^{4.69}$ CFU to $1 \times 10^{6.81}$ CFU ml^{-1} when death was recorded 48–72 h after intra-peritoneal inoculation.

Bacteria-free exotoxin, the extracellular preparation of *A. hydrophila*, was able to produce similar mild symptoms in a few fishes 10 days post-inoculation, thereby indicating the role of exotoxin in the disease. The isolates produced virulence factors like proteolytic enzymes, amylolytic enzymes, DNase, haemolysins and haemagglutinin. The results of experimental infection, virulence factors and the earlier reports on virulence factors[4–6,10–11] together amply substantiate the less virulent nature of the present isolate. Great variations in virulence factor production among the various strains of *A. hydrophila* have been reported[12]. Common relationship between *in vitro* virulence-factor production and biological virulence of *A. hydrophila* has not been established[9,13]. Therefore, it can be said that the production of virulence factors *in vivo*, augments the complex process of pathogenesis by interacting intricately with the host factor delineating the progression of the disease process, and *in vitro* production of different virulence factor(s) do not qualify a strain to be classified as virulent or avirulent[14].

The whole-cell antisera raised in rabbits, when adsorbed by the highly virulent *A. hydrophila* from acute dropsy, still could show mild positive slide agglutination reaction with the whole-cell bacterial antigen prepared out of the present isolate. Similarly, the whole-cell bacterial antigen, but not the extsracellular preparation (ECP), gave diffused precipitation reaction in agar gel immuno diffusion with the adsorbed antisera. Soluble antigen released from washed whole cells of both the isolates after five cycles of slow freezing, at –86°C, and quick thawing at 40°C, were analysed by 5–15% gradient SDS-polyacrylamide gel electrophoresis, SDS-PAGE[15]. Comparative polypeptide profiles of the present isolate revealed minor differences in polypeptides in the range of 40–42 kDa mol wt (Figure 2). These clearly indicated that the present isolate was a different strain than the earlier reported one which caused acute infection.

Unlike earlier reports of catla suffering from dropsy infection[1], an ulcerative infection[3], and septicemia due to *A. hydrophila* infection[4], we have reported here the atypical chronic form of dropsy caused by a different strain of *A. hydrophila*, specifically infecting *C. catla*. Further studies in this area will help to understand in greater detail the species susceptibility and various disease spectra caused by different strains of *A. hydrophila*.

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Mapping life sciences research in India: A profile based on *BIOSIS* 1992–1994

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Life sciences research in India, as seen from Biological Abstracts (1992–1994), is quantified and mapped. Researchers from over 1,400 institutions located in over 450 cities/towns have authored 20,046 papers in 1,582 journals published from 52 countries. About 46% of Indian papers have appeared in non-SCI journals, and a further 37.5% in journals with impact factor less than 1.0. The analysis reveals the existence of two clusters: a large number of institutions devoted to agriculture and classical biology, publishing mostly in low-impact journals, and a smaller group publishing some papers in new biology and some areas of medicine in international journals of medium impact.

THIS paper aims to map life sciences research in India as reflected by the journal literature, using standard techniques of scientometrics. This is a macroscopic study, going down to the institutional level. No effort is made to analyse the data at the level of individual investigators.

Biology at centre stage

Biology today is on the fast-forward mode and is making rapid strides on many fronts. Ever since Watson and Crick published their brief note on the structure of DNA in *Nature* in April 1953, biology has been on the upswing. It became increasingly interdisciplinary and soon edged its way to the centre stage, dislodging physics. The transition from classical biology, largely concerned with structure and function at the organism level, to new biology, with its overwhelming and almost reductionist concern for finding molecular-level understanding of all biological phenomena, brought forth many challenges that could not obviously be answered by classical biology. The challenge posed by the complexity of living systems has attracted such scientists as Philip Anderson, Nobel laureate in physics, who a few years ago taught a biology course at Princeton to graduate students of physics. Thanks to the growing perception that a deeper understanding of complex biological systems will need a more quantitative type of biology that is closely integrated with the physical sciences, several front-ranking US universities are starting new institutes to bring physical and biomedical scientists together, according to a report in *Nature* (1999, **397**, 3). At Stanford, for instance, Nobel prize-winning physicist Steven Chu, who works on the behaviour of single protein molecules, and biochemist James Spudich are planning such an interdisciplinary research centre with about 50 faculty members. In addition, Princeton University plans to establish within the next two years an interdisciplinary genomics institute, and Chicago University approved in June 1997 the formation of an interdivisional institute. The training of the next generation of biologists, says developmental geneticist Shirley Tilghman of Princeton University, will include more mathematics, physics and chemistry. Life scientists have their own newspaper, the 12-year-old bi-weekly *The Scientist*, edited and published by Eugene Garfield, inventor of *Current Contents* and *Science Citation Index* (SCI); furthermore, many web sites on the Internet provide a whole range of information to biologists. Biology is becoming so popular, that it may overtake humanities as the foundation of American undergraduate education, according to Joseph Perpich of the Howard Hughes Medical Institute, probably America's largest philanthropy funding life science research. More than 50,000 students now receive Bachelor degrees in biology each year in the US alone. 'We are beginning to see quite remarkable research and papers co-authored by undergraduates that you just wouldn't have seen 20 years ago', Perpich says. A recent US National Research Council report, however, warns that the stream of life science students entering the graduate school pipeline should be frozen to prevent research job applications from flooding the market.

Mega projects such as the Human Genome Project, the worldwide search for a vaccine for AIDS, viagra jokes and novels like Carl Djerassi's *NO* make sure that biology is never short of media attention. Life sciences research receives far more funding now than ever before. Today life science domains – biology, biomedicine, and clinical medicine – account for 55% of the

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world's publications and 63% of US publications in science, technology and medicine[1], as seen from the journal literature of 1995, comprising papers published in about 4,800 journals selected by the Institute for Scientific Information, Philadelphia in 1981 as the base for *SCI*. The sub-fields under these broad groups as given in NSF's *Science and Engineering Indicators* 1998 appear in Table 1. In contrast, life science research accounts for less than 33% of India's contribution to the journal literature of science and technology (Table 2).

Life sciences in India

As in other fields before, India caught on to new biology after a time lag. However, currently new biology is well-funded in India (relative to other fields), and the field is picking up. In a 1997 meeting on Indian biology for the year 2000 and beyond (IBY2K) at Hyderbad's Centre for Cellular and Molecular Biology (CCMB), less than 5 of the more than 50 papers presented were in classical biology.

This paper looks at India's contributions to life sciences research in the journal literature, as reflected by the CD-ROM edition of *BIOSIS Biological Abstracts* 1992–1994 (Silver Platter). This paper aims to examine the following:

(i) The volume of work published from India;
(ii) Journals often used, their standing (as reflected by their impact factors) and country of publication;
(iii) Sub-fields in which Indian researchers are active; and
(iv) Indian institutions actively publishing.

Arunachalam and Singh[2-5] used print versions of both INSPEC *Physics Abstracts* and *SCI* to quantify India's contribution to some high-tech areas in physics such as lasers, holography, liquid crystals and superconductivity.

Table 1. Broad fields and sub-fields included under 'life sciences'

Clinical medicine	
Addictive diseases	Allergy
Anesthesiology	Arthritis and rheumatism
Cancer	Cardiovascular system
Dentistry	Dermatology and venereal disease
Endocrinology	Fertility
Gastroenterology	General and internal medicine
Geriatrics	Hematology
Hygiene and public health	Immunology
Miscellaneous clinical medicine	Nephrology
Neurology, neurosurgery	Obstetrics, gynaecology
Ophthalmology	Orthopedics
Otorhinolaryngology	Pathology
Pediatrics	Pharmacology
Pharmacy	Psychiatry
Radiology and nuclear medicine	Respiratory system
Surgery	Tropical medicine
Urology	Veterinary medicine
Biomedical research	
Anatomy and morphology	Biochemistry and molecular biology
Biomedical engineering	Biophysics
Cell biology, cytology and histology	Embryology
General Biomedical research	Genetics and heredity
Microbiology	Microscopy
Miscellaneous biomedical research	Nutrition and dietetics
Parasitology	Physiology
Virology	
Biology	
Agriculture and food science	Botany
Dairy and animal science	Ecology
Entomology	General biology
General zoology	Marine biology and hydro-biology
Miscellaneous biology	Miscellaneous zoology

Other broad fields constituting the whole of science and technology are chemistry, physics, earth and space sciences, engineering and technology, and mathematics.

Source: *Science and Engineering Indicators 1998*, NSF, USA, p. A-268 (ref. 1)

Table 2. Distribution of scientific and technical papers for selected countries by field, 1995 (ref. 1)

Field	World	India	USA	UK	Germany	France	Israel	Japan
All S & T fields, No. of papers	438,767	7,851	142,942	32,980	30,654	23,811	4,322	39,498
Clinical medicine, %	30.7	12.2	35.3	38.3	28.4	28.4	34.1	29.0
Biomed. research, %	16.4	13.3	19.7	17.5	14.9	16.9	14.9	15.5
Biology, %	8.0	7.3	7.8	8.1	6.0	5.8	9.0	6.6
Chemistry, %	14.0	30.3	9.0	10.8	17.9	15.4	7.5	16.9
Physics, %	16.9	21.2	12.5	12.0	21.2	19.2	20.5	21.2
Earth and space science, %	5.3	4.8	6.6	5.6	3.9	5.1	4.1	2.5
Engineering and technology, %	7.0	9.9	7.2	6.3	5.9	5.7	6.6	7.6
Mathematics, %	1.8	1.0	2.0	1.4	1.8	3.5	3.3	0.7

Source: *Science and Engineering Indicators 1998*, NSF, based on the 1981 ISI constant journal set of about 4,800 journals.

Arunachalam and Singh[6] have also analysed India's contribution to the world literature of science using *SCI*. Recently, I have quantified and mapped India's contributions to the literatures of mathematics[7], materials science[8], physics[9], medicine[10], agriculture[11] and science in general[12], using electronic versions of appropriate international bibliographic databases. Encouragingly, the study on medical research in India, published in *Current Science*[13] and the *National Medical Journal of India*[14], has attracted considerable attention[15-23], perhaps because the study addressed the question of relevance of research to local concerns.

Methodology

All papers having a first author address in India were downloaded from *BIOSIS Biological Abstracts* 1992–1994. Incidentally, unlike *SCI*, *BIOSIS* lists the names and addresses of only the first author. Therefore, papers in which Indian authors were not listed as first authors were not captured. The fields downloaded were corporate source or author affiliation (CS), source or journal title including volume and page (SO), and publication year (PY). Names of institutions were standardized. For example, Haryana Agricultural University was merged with CCS Haryana Agricultural University, and University of Saugar merged with Dr H. S. Gour Vishwavidyalaya; names of departments were dropped. Names of states were added to all cities and towns found in the Indian addresses. In addition the following were added to journal titles: country of origin of journals (seen from *Serial Sources for the BIOSIS Previews Database 1993* obtained from BIOSIS, USA) impact factor values from *Journal Citation Reports* (*JCR*) 1992 and 1994; and sub-field classifications for journals, mostly from *SCI Guide* and for some from *Ulrich*. Individual papers were not assigned to sub-fields, since that would take enormous effort and demand considerable amount of subject expertise. Assigning of journals to sub-fields instead was adequate for the kind of mapping exercise undertaken. The data were converted into a database and analysed using FoxPro.

Analysis

For this study, I considered only the journal literature indexed in the CD-ROM edition of *BIOSIS Biological Abstracts* 1992–1994. Here the years indicate the disc years and not the years of publication of the individual papers. In the three years considered, Indian researchers published 20,046 papers. Table 3 lists journals often used by Indian researchers to publish their work in descending order of the number of papers published. Indian researchers published more than 100 papers in the three years in 37 journals and more than 50 papers in 84 journals. At the other extreme, they published only one paper in each of the 482 journals and two papers in each of the 248 journals. Figure 1 shows that the distribution of papers among journals is very nearly Bradfordian. The country of publication of each journal, impact factor (from *JCR* 1994) and the sub-field classification of the journal (mostly from *SCI Guide* and in some cases *Ulrich*) are also given in Table 3. Many journals indexed in *BIOSIS* are not indexed in *SCI*, and therefore they are not included in *JCR*. These journals were assigned an impact factor of 0.0; for some journals, the impact factor column is left blank in *JCR* and the impact factor for these journals is shown as 0.0. Some journals are classified into two or more sub-field categories, e.g. *Bioresource Technology*, a UK journal, is classified into energy, biotechnology and agriculture. More than 700 journals have no papers from India either in 1992 or in 1993–1994. Many of these journals were indexed in *BIOSIS* in both these periods, but had not indexed any paper from India in one of the periods. Some other journals, including such important titles as *Indian Journal of Biochemistry and Biophysics* and *Journal of Biosciences*, are not indexed at all in *BIOSIS* in one of the two periods. Editors of Indian journals should keep in touch with editors and publishers of

Table 3. Journals often used by Indian researchers to publish their work in life sciences

Journal title	Sub-field	Journal country	Impact factor–94	Impact factor–92	No. of papers
Indian journals					
Indian Journal of Experimental Biology	Biology	IND	0.000	0.000	593
Indian Veterinary Journal	Vet sci	IND	0.004	0.007	566
Indian Journal of Agronomy	Agricul	IND	0.002	0.000	448
Indian Journal of Animal Sciences	Agri, Dairy	IND	0.014	0.017	424
Journal of Maharashtra Agricultural Universities	Agricul	IND	0.000	0.000	413
Journal of the Indian Society of Soil Science	Agri, Soil	IND	0.000	0.000	402
Indian Journal of Agricultural Sciences	Agricul	IND	0.026	0.008	333
Journal of Food Science and Technology	Food sci	IND	0.026	0.059	286
Crop Research (Hissar)	Agricul	IND	0.000	0.000	280
Indian Forester	Forestry	IND	0.000	0.000	233
Acta Botanica Indica	Plant sci	IND	0.000	0.000	228
Current Science	Multidis sci	IND	0.271	0.253	226
Proceedings of the National Academy of Sciences India Section B (Biological Sciences)	Biology	IND	0.000	0.000	186
Indian Journal of Plant Physiology	Plant sci	IND	0.000	0.000	182
Indian Journal of Genetics and Plant Breeding	Plant sci//Genetics	IND	0.000	0.000	159
Indian Journal of Physiology and Pharmacology	Pharmacol//Physiol	IND	0.000	0.000	156
Advances in Plant Sciences	Plant sci	IND	0.000	0.000	151
Journal of Entomological Research (New Delhi)	Entomol	IND	0.000	0.000	151
Foreign journals					
Phytochemistry (Oxford)	Plant sci	UKD	1.157	1.113	148
Cytologia (Tokyo)	Cell biol	JPN	0.000	0.000	85
Fitoterapia	Plant sci	ITA	0.000	0.000	84
World Journal of Microbiology and Biotechnology	Biotech//Microbiol	UKD	0.382	0.385	81
Tetrahedron	Chem, org	UKD	2.277	2.830	64
Tetrahedron Letters	Chem, org	UKD	2.378	2.321	64
Mutation Research	Genetics//Biochem//Agricul	UKD	1.975	1.960	62
Biologia Plantarum (Prague)	Plant sci	CSK	0.168	0.215	61
Bioresource Technology	Energy//Biotech//Agricul	UKD	0.785	0.558	59

Source: *BIOSIS* 1992–94.

secondary services (such as *Current Contents*, *BIOSIS*, and *SCI*) and ensure timely coverage of their journals in these services.

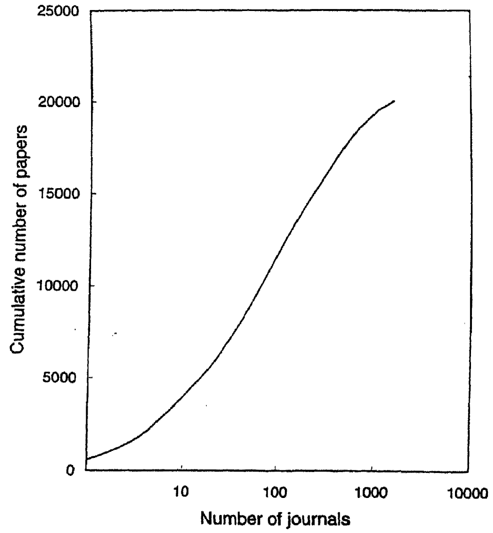

Figure 1. Number of journals vs cumulative number of Indian papers (source: *BIOSIS* 1992–1994).

Use of letters journals

Only about 2% of the papers have appeared in letters journals (Table 4). Indian life scientists used 26 letters journals to publish 416 papers, and even among these more than 90 papers are not in life sciences proper: (i) 64 papers published in *Tetrahedron Letters* are in the area of organic chemistry; (ii) 18 published in *Analytical Letters* are about analytical chemistry; (iii) Eight papers published in *Acta Crystallographica Section C* concern crystallography; (iv) Two papers in *Newsletters on Stratigraphy* are in the area of geology; and (v) one paper published in *Synthetic Communications* is in organic chemistry. All journals that have the word 'letters' or 'communication(s)' in their titles appear in Table 4 with the exception of *Biochemical and Biophysical Research Communications*, which publishes short papers. In contrast, in physics Indian researchers publish a much higher percentage of papers in letters journals[9].

Table 4. Letters and communication journals used by Indian researchers as seen from *BIOSIS* 1992–94

Journal title	Publication country	Impact factor–94	Impact factor–92	No. of papers
Tetrahedron Letters	UKD	2.378	2.321	64
Biotechnology Letters	UKD	0.976	1.110	53
FEMS (Federation of European Microbiological Societies) Microbiology Letters	NLD	1.597	1.334	46
FEBS (Federation of European Biochemical Societies) Letters	NLD	3.600	3.505	38
Letters in Applied Microbiology	UKD	1.040	1.042	38
Cancer Letters	NLD	1.264	1.137	36
Bioorganic and Medicinal Chemistry Letters	UKD	1.425	1.217	27
Analytical Letters	USA	0.950	1.000	18
Neuroscience Letters	NLD	2.703	2.419	14
Biomedical Letters	UKD	0.000	0.000	13
Cereal Research Communications	HUN	0.102	0.288	12
Immunology Letters	NLD	1.223	1.559	11
Acta Crystallographica Section C Crystal Structure Communications	DEN	0.458	0.479	9
Veterinary Research Communications	NLD	0.592	0.414	8
Communications in Soil Science and Plant Analysis	USA	0.394	0.485	6
Toxicology Letters (Amsterdam)	NLD	1.112	0.774	6
Neuroendocrinology Letters	DEU	0.703	0.395	4
Drug and Chemical Toxicology and International Journal for Rapid Communication	USA	0.532	0.347	3
Newsletters on Stratigraphy	DEU	0.000	0.000	2
Research Communications in Chemical Pathology and Pharmacology	USA	0.780	0.599	2
Cryo Letters	UKD	0.685	1.080	1
Journal of the Chemical Society Chemical Communications	UKD	2.575	2.511	1
Neuroscience Research Communications	UKD	0.917	0.969	1
Nuclear Medicine Communications	UKD	1.078	0.982	1
Rapid Communications in Mass Spectrometry	UKD	2.484	0.000	1
Synthetic Communications	USA	0.699	0.716	1
Total				416

Only journals having the words 'letters' or 'communication(s)' in their title are included in this table. Some journals, such as *Biochemical and Biophysical Research Communications*, may not be letters journals.

Classification by sub-field

Table 5 displays the number of journals under each sub-field in which Indian researchers have published papers, along with the total number of papers from India in the different sub-fields. In order to avoid duplication, a journal is alloted to only one sub-field. For example, *Indian Journal of Genetics and Plant Breeding* is included in plant science and not in genetics. Of the 110 sub-fields, agriculture (2,824 papers), plant science (2,300 papers), biology (1,341 papers) and veterinary science (1,024 papers) are the sub-fields in which Indian researchers are most active. A large majority of life science research in India centers on agriculture and classical biology, while among sub-fields of new biology, biochemistry and molecular biology (674 papers) is an area of more than moderate activity.

Classification by journal country

Table 6 lists the countries bringing out journals in which Indian researchers have published their papers. More than 55% of papers from India have appeared in 118 Indian journals with Indian researchers also publishing many papers in British (2,570 papers or more than 12.8%) and US journals (1,964 papers or 9.8%). These are followed by journals published in The Netherlands, Germany, Switzerland and Japan. In all, Indian researchers have published in journals from 52 countries.

Let us compare the extent of publication in foreign journals by Indian scientists in different fields. Close to 77% of Indian papers indexed in *CAB Abstracts* (agriculture and related fields)[11], 18% of papers in physics (indexed in *INSPEC-Physics*)[9], 33.5% of papers in medicine (indexed in *Medline*)[13], 35% of papers indexed in *Mathsci* (mathematics and related fields)[7], and 9.5% of papers indexed in *Materials Science Citation Index*[8] were published in Indian journals. There is considerable overlap in the coverage of literature in *BIOSIS* and *CAB Abstracts* and no wonder that agriculture and biology are the fields in which Indian scientists publish their findings predominantly in Indian journals.

At least 7 journals in the top ten of the 118 Indian journals used by Indian life scientists concern agriculture. Of the 50 journals most often used by Indian researchers to publish their work, only 5 are foreign journals: *Phytochemistry* (United Kingdom), *Biochemistry International* (Australia) which has been renamed *Biochemistry and Molecular Biology International*,

Table 5. Indian research papers covered by *BIOSIS* 1992–94 classified by sub-fields (arranged by number of papers)

Sub-field	No. of journals	No. of papers
Agriculture	54	2824
Plant science	112	2300
Biology	33	1341
Veterinary sciences	25	1024
Agriculture, Dairy and Animal science	17	861
Pharmacology and Pharmacy	64	789
Biochemistry and Molecular biology	66	674
Agriculture, Soil science	15	583
Food Science and technology	32	580
Zoology	57	554
Entomology	46	547
Environmental sciences	35	391
Microbiology	37	383
Medicine, general and internal	36	354
Chemistry, organic	14	352
Multidisciplinary sciences	15	329
Forestry	9	291
Tropical medicine	11	270
Biotechnology and Applied microbiology	12	261
Genetics and Heredity	39	251
Pediatrics	15	211
Medicine, research and experimental	15	204
Oncology	28	202
Ecology	20	200
Cell biology	24	196
Biophysics	12	190
Public health	22	171
Fisheries	13	155
Immunology	31	145
Chemistry, analytical	21	142
Toxicology	21	135
Neurosciences	43	134
Geosciences	8	119
Chemistry	14	118
Cardiovascular system	22	111
Oceanography	9	105
Physiology	15	105
Ophthalmology	13	102
72 other sub-fields	499	2327
Unknown	8	15
Total	7455	20,046

Journals (and papers published in them) are included in only one sub-field, even though the journal may have relevance to more than one sub-field.

Table 6. Indian research papers covered by *BIOSIS* 1992–94 classified by sub-fields (arranged by number of papers)

Journal country	No. of journals	No. of papers	% of papers in world journals
India	118	11,109	55.42
UK	345	2570	12.82
USA	409	1964	9.80
The Netherlands	148	1347	6.72
Germany	146	889	4.43
Switzerland	64	274	1.37
Japan	56	261	1.30
Czech republic	11	227	1.13
Australia	18	195	0.97
Italy	32	175	0.87
Denmark	29	154	0.77
France	32	105	0.52
Hungary	13	72	
Poland	19	62	
Pakistan	7	50	
37 other countries	135	592	
Total	1582	20,046	

Cytologia (Japan), *Fitoterapia* (Italy), and *World Journal of Microbiology and Biotechnology* (United Kingdom). Similar lists for physics[9] and chemistry contain many more foreign journals. There are two reasons for this difference. (i) A large part of biological science research done in India is in the areas of agriculture (including veterinary science and dairy science) and classical biology. The classical biology work done in India, with a few exceptions, is not of great current interest to researchers in the scientifically advanced countries and it may be difficult to get Indian papers in this area published in good foreign journals. Much of what is done in agriculture is of considerable local interest and publishing such research in Indian journals may serve the purpose better than publishing it in foreign journals. Then there are medical journals such as *Indian Pediatrics* and *Indian Journal of Medical Research*, which carry articles of relevance to the Indian situation; (ii) India's share of new biology literature is rather small, and these papers are scattered in a number of journals. The 4 frequently used foreign journals in new biology are: *Biochemistry International* (Australia), 143 papers; *World Journal of Microbiology and Biotechnology* (UK), 81 papers; *Mutation Research* (The Netherlands), 62 papers; and *Biochimica Biophysica Acta* (The Netherlands), 56 papers.

Classification by journal impact factor

The journals publishing Indian papers considered in this study are classified into different ranges of impact factors as seen from *JCR* 1992 and 1994 in Tables 7 *a* and *b* respectively. We see that a very large number of papers, about 84%, have appeared in journals whose impact factor is either zero (meaning these journals are not included in *SCI*) or less than 1.0. About two-thirds of the journals used are in this lowest impact category. At the other extreme, 54 papers have been published in 10 journals whose impact factor (IF 92) is higher than 6.0, and 103 papers appeared in 24 journals with an impact

Table 7*a*. Distribution of Indian life sciences papers by impact factor range of journals (based on impact factor data from *JCR* 1992)

IF range (*JCR* 1992)	No. of journals	No. of papers
0.000	443	9861
>0.0–0.5	305	4944
>0.5–1.0	326	2127
>1.0–1.5	206	1494
>1.5–2.0	125	716
>2.0–2.5	62	339
>2.5–3.0	39	196
>3.0–3.5	24	98
>3.5–4.0	11	132
>4.0–4.5	13	29
>4.5–5.0	4	7
>5.0–5.5	10	44
>5.5–6.0	4	5
>6.0–6.5	2	2
>6.5–7.0	2	35
>8.0	6	17
Total	1582	20,046

Table 7*b*. Distribution of Indian life sciences papers by impact factor range of journals (based on impact factor data from *JCR* 1994)

IF range (*JCR* 1994)	No. of journals	No. of papers
0.000	408	9310
>0.0–0.5	289	5166
>0.5–1.0	345	2337
>1.0–1.5	207	1487
>1.5–2.0	129	658
>2.0–2.5	73	417
>2.5–3.0	44	256
>3.0–3.5	27	145
>3.5–4.0	10	82
>4.0–4.5	15	61
>4.5–5.0	13	21
>5.0–5.5	4	22
>5.5–6.0	3	12
>6.0–6.5	3	15
>6.5–7.0	2	2
>7.0–7.5	2	7
>7.5–8.0	1	30
>8.0	7	18
Total	1582	20,046

factor of over 5.0. There was a slight increase in the impact factor of many journals between 1992 and 1994. For example, there are 15 journals with a 1994 impact factor higher than 6.0 (as against 10 in 1992), and these journals published 72 Indian papers in the three years under study (as against 54 in the 10 journals whose 1992 impact factor was above 6.0).

Classification by institution

Leading Indian institutions whose work is indexed in *BIOSIS* 1992–1994 are listed in Table 8. There are 3 agricultural universities and 2 medical education and research institutes in the top 7 institutions. Banaras Hindu University (BHU), University of Delhi, University of Calcutta and Indian Institute of Science (IISc) are among the most prolific publishers of life sciences research in India. Fourteen institutions have published more than 200 papers, and 35 have published between 100 and 200 papers in the three years considered. Leaving out home addresses, one finds that life science research is published from over 1,400 institutions in India. The distribution of papers over institutions follows a typical Bradford curve (Figure 2). Academic institutions consisting of general, agricultural and medical universities and colleges and engineering colleges account for 64.5% of all papers from India (Figure 3). Scientific agencies of the Central Government such as the Indian Council of Agricultural Research (1,708 papers), Council of Scientific and Industrial Research (1,545 papers), and Indian Council of Medical Research (416 papers) have published 4,179 papers (about 21%). Organizations under the Central Ministries account for 1,092 papers. The reason for the greater volume of work at the higher educational institutions, compared to the better-endowed national laboratories, is the presence of a very large number of doctoral students. Unlike scientists in various Central Government laboratories, who enjoy the benefits of a decent income, job security and no penalties for non-performance, the students have to perform well to be able to make a career or to win overseas fellowships.

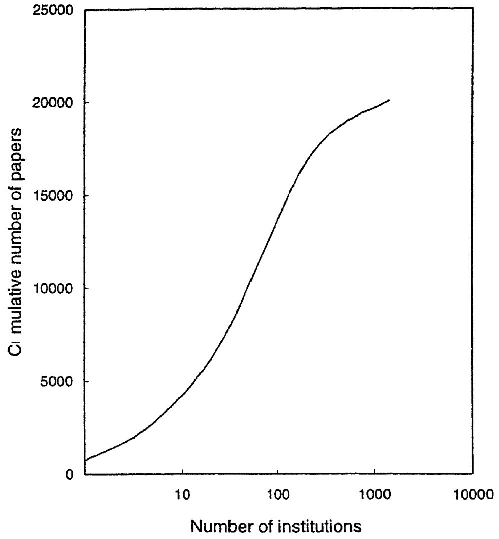

Figure 2. Number of institutions vs cumulative number of Indian papers (source: *BIOSIS* 1992–1994).

Table 8. Indian institutions publishing papers as seen from *BIOSIS* 1992–94

Institute	City/town	No. of papers
Chaudhary Charan Singh Haryana Agri University	Hissar	752
Punjab Agri University	Ludhiana	692
Banaras Hindu University	Varanasi	440
All India Institute of Med Science	New Delhi	372
Indian Agri Research Institute	New Delhi	367
University of Delhi	New Delhi	316
Postgraduate Institute Med Education Research	Chandigarh	295
University of Calcutta	Calcutta	271
Indian Institute Science	Bangalore	224
Himachal Pradesh Krishi Vishvavidyalaya	Palampur	222
Central Food Technological Research Institute	Mysore	221
Central Drug Research Institute	Lucknow	216
Aligarh Muslim University	Aligarh	215
Indian Vet Research Institute	Izatnagar	209
GB Pant University of Agriculture and Technology	Pantnagar	186
Bhabha Atomic Research Centre	Mumbai	173
Bidhan Chandra Krishi Viswavidyalaya	Kalyani	169
Marathwada Agri University	Parbhani	169
Punjabrao Krishi Vidyapeeth	Akola	169
National Chemical Laboratory	Pune	168
Jawaharlal Nehru University	New Delhi	163
Panjab University	Chandigarh	163
Indian Institute of Chemical Biology	Calcutta	136
National Institute of Immunology	New Delhi	120
Indian Institute of Chemical Technology	Hyderabad	99
Center for Cellular and Molecular Biology	Hyderabad	86
Other 1381 Addresses		12,978
Private Addresses		455
Total		20,046

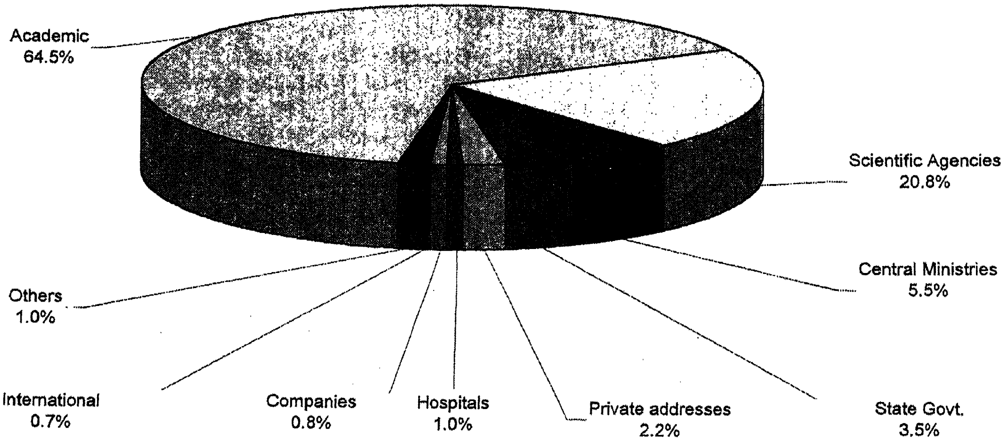

Figure 3. Contributions made by different types of organizations as seen from *BIOSIS* 1992–1994.

Classification by city and state

Tables 9 and 10 present the number of papers published from different cities/towns and states of India with Uttar Pradesh, Maharashtra and Delhi as leaders. In particular, Delhi (1,935 papers) leads the rest of the cities by a large margin which is largely because of the concentration of varied research institutions in the capital. Four other cities, viz. Calcutta, Lucknow, Mumbai, and Bangalore have published more than 800 papers. Ludhiana and Hissar, largely thanks to the Punjab and CSS Haryana Agricultural University, and Hyderabad have published more than 700 papers each. In total, papers have come from more than 450 Indian cities and towns, of which 47 have published at least 100 papers in the three years and 82 more than 50 papers.

Use of high-impact journals

Table 11 provides the number of papers published by some large institutions (prolific publishers) in journals of different impact factors (as given in *JCR* 1994). One has to be extremely cautious in interpreting the data presented in this table. Ideally, one should count the actual number of times a paper is cited and see in which journals these citations occur, rather than merely look at the impact factor of the journal in which a paper is published. Very often Indian authors publish papers in journals above a certain threshold impact factor, but these papers do not get cited as often as would be expected on the basis of the impact factors of the journals. In an earlier paper I showed that Indian papers often lower the impact factors of journals. Tibor Braun and colleagues have demonstrated that in most fields the relative citation rates of India (ratios of actual citation rate/expected citation rate) is less than one.

Since the impact factors of agricultural and classical biology journals are low, not many highly cited papers emerge from agricultural universities. As pointed out in my report on agricultural research in India[11], communication habits differ from field to field, and results of agricultural research are best published in local/national journals. Institutions carrying out work in new biology and medicine have a better chance of placing some of

Table 9. Indian cities/towns contributing to the world literature of life sciences as seen from *BIOSIS* 1992–94 (arranged by number of papers)

City/town	State	No. of papers
Delhi	Delhi	1935
Calcutta	West Bengal	1000
Lucknow	Uttar Pradesh	845
Mumbai	Maharashtra	816
Bangalore	Karnataka	812
Hyderabad	Andhra Pradesh	793
Hissar	Haryana	783
Ludhiana	Punjab	713
Chennai	Tamil Nadu	575
Chandigarh	Chandigarh	502
Varanasi	Uttar Pradesh	455
Mysore	Karnataka	365
Pune	Maharashtra	353
Izatnagar	Uttar Pradesh	257
Kalyani	West Bengal	250
Coimbatore	Tamil Nadu	245
Jabalpur	Madhya Pradesh	240
Palampur	Himachal Pradesh	232
Aligarh	Uttar Pradesh	222
Karnal	Haryana	190
Pantnagar	Uttar Pradesh	186
Anand	Gujarat	184
Bhubaneswar	Orissa	178
Trichur	Kerala	178
Ankola	Maharashtra	175
433 other towns		7562
	Total	20,046

Table 10. Indian states contributing to the world literature of life science as seen from *BIOSIS* 1992–94

State	No. of Indian papers
Uttar Pradesh	2471
Maharashtra	2010
Delhi	1935
West Bengal	1581
Karnataka	1569
Tamil Nadu	1424
Andhra Pradesh	1398
Haryana	1141
Kerala	1114
Punjab	862
Madhya Pradesh	739
Gujarat	650
Chandigarh	512
Rajasthan	448
Bihar	442
Himachal Pradesh	420
Orissa	344
Jammu and Kashmir	242
Assam	197
Meghalaya	159
Pondicherry	136
Goa	124
Andaman and Nicobar	32
Manipur	31
Sikkim	22
Tripura	17
Arunachal Pradesh	3
Mizoram	1
Unknown	30
Total	20,046

Table 11. India's contribution to the world literature of life sciences categorized by leading institutions and impact factors (IF 94) of journals used

	Impact factor range (IF 94)															
Institution	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Total
CCS Haryana Agri University	360	293	57	40	2	0	0	0	0	0	0	0	0	0	0	752
Punjab Agri University	375	208	84	21	2	0	2	0	0	0	0	0	0	0	0	692
Banaras Hindu University	180	98	71	62	17	3	5	4	0	0	0	0	0	0	0	440
All India Inst Med Science	105	99	52	41	21	25	12	6	3	1	1	1	3	0	2	372
Indian Agri Research Institute	200	96	35	25	7	1	2	0	1	0	0	0	0	0	0	367
University of Delhi	101	60	55	41	22	14	15	2	2	1	2	0	0	1	0	316
Postgraduate Institute Med Educ and Research, Chandigarh	57	82	60	38	26	14	10	2	3	0	1	0	0	0	2	295
University of Calcutta	123	69	25	29	8	7	5	3	1	1	0	0	0	0	0	271
Indian Institute of Science	20	46	17	39	17	24	10	14	7	10	0	2	7	7	4	224
Himachal Pradesh Krishi Vishwavidyalaya	113	89	15	3	1	0	1	0	0	0	0	0	0	0	0	222
Central Food Technological Research Institute	39	72	72	22	10	1	3	1	1	0	0	0	0	0	0	221
Central Drug Research Institute	96	33	31	21	12	13	1	5	2	1	1	0	0	0	0	216
Aligarh Muslim University	121	30	31	18	5	4	0	0	0	1	0	0	0	0	0	215
Indian Vet Research Institute	51	122	23	8	4	1	0	0	0	0	0	0	0	0	0	209
Bhabha Atomic Research Centre	37	40	44	26	12	4	2	5	2	0	0	0	1	0	0	173
National Chemical Laboratory	16	49	28	21	17	19	3	5	3	6	0	0	1	0	0	168
Jawaharalal Nehru University	29	52	19	18	12	11	7	8	1	1	1	2	0	2	0	163
Panjab University	59	45	34	17	3	3	2	0	0	0	0	0	0	0	0	163
University of Madras	51	39	37	15	9	4	1	1	0	0	0	0	0	0	0	157
Indian Institute of Chemical Biology	10	22	19	33	9	21	6	4	1	5	2	1	1	2	0	136
National Institute of Immunology	13	14	19	17	8	20	8	2	6	4	3	0	0	6	0	120
Indian Institute of Chemical Technology	8	8	19	20	4	33	7	0	0	0	0	0	0	0	0	99
Center for Cellular and Molecular Biology	6	16	7	3	5	5	8	6	13	7	0	8	0	2	0	86
	2170	1682	854	578	233	227	115	68	46	38	11	14	13	20	8	6077

A, 0.0; B, > 0.0 – <= 0.5; C, > 0.5 – <= 1.0; D, > 1.0 – <= 1.5; E, > 1.5 – <=2.0; F, > 2.0 – <= 2.5; G, > 2.5 – <= 3.0; H, > 3.0 – <=3.5; I, > 3.5 – <= 4.0; J, > 4.0 – <= 4.5; K, > 4.5 – <= 5.0; L, > 5.0 – <= 6.0; M, > 6.0 – <= 7.0; N, > 7.0 – <= 8.0; O, > 8.0.
Source: *BIOSIS* 1992–94.

their papers in high impact journals. IISc, for example, has published 61 out of 284 papers in journals with impact factors higher than 2.5. CCMB has published 44 papers, about half of its entire output, in journals with impact factors higher than 2.5. National Institute of Immunology (NII) has 29 papers, Indian Institute of Chemical Biology 22 papers, and University of Delhi 37 papers in journals with impact factors higher than 2.5. The Post-graduate Institute of Medical Education and Research, Chandigarh, has 18 papers, All India Institute of Medical Sciences (AIIMS) 29 papers, and National Chemical Laboratory (NCL) 18 papers in this list. Scientists from some of these institutions also publish their work in non-*SCI* journals, mostly Indian journals (such as *Indian Journal of Experimental Biology*) that could, with a little improvement, get into *SCI*.

In all, India as a whole has published 671 papers (about 3.35% of all papers) in journals with an impact factor (IF 94) higher than 2.5 and 270 papers in journals with an impact factor higher than 4.0. In these high impact journals (IF 94 > 4.0), Indian researchers have published 103 papers in biochemistry and molecular biology, 11 in microbiology, 10 each in general medicine and immunology, 4 in development biology, and 3 in endocrinology. Of the 190 papers in biophysics, 41 were published in journals whose impact factors were higher than 3.5. As pointed out by C. N. R. Rao, one of India's leading policy makers and a prolific publisher of research papers, Indian researchers find it difficult to place their papers in high impact journals. Among the papers indexed in *BIOSIS* 1992–94, only 2 papers in *Nature* and 6 in *Lancet* are from India. Indian researchers, however, manage to publish a larger number of papers in decent biochemistry journals. In the three years considered, they have published 30 papers in *Journal of Biological Chemistry*, 17 in *Biochemistry*, 56 in *Biochimica et Biophysica Acta*, 13 in *Journal of Molecular Biology*, 48 in *Biochemical and Biophysical Research Communications*, 21 in *Biochemical Journal*, and 19 in *European Journal of Biochemistry*. Apart from biochemistry and molecular biology (238 of the 674 papers), Indian researchers have published in medium-high impact journals (IF > 2.5 in *JCR* 1994) in neuroscience (46 papers), biophysics (41 papers), microbiology (41 papers), immunology (39 papers) and genetics (33 papers). A small number of institutions account for a large percentage of papers in high impact journals. Scientists at IISc have published 8 of the 30 Indian papers in *Journal of Biological Chemistry*, 7 of the 13 Indian papers in *Journal of Molecular Biology*, 1 in *Journal of Immunology*, and 1 in *Nature*. Scientists at that Indian Institute of Chemical Biology have published 7 papers in *Journal of Biological Chemistry*. AIIMS had 1 paper in *Journal of Molecular Biology*, 2 papers in *American Review of Respiratory Diseases*, 2 in *Hepatology*, 2 in *Lancet*, and 1 in *Arthritis*. The International Centre for Genetic Engineering and Biotechnology had 4 papers in *Journal of Immunology* and 1 in *Journal of Biological Chemistry*. All 4 Indian papers in *Journal of Biomolecular NMR* came from Tata Institute of Fundamental Research (TIFR). The only Indian paper in *FASEB Journal* came from the Christian Medical College in Vellore, and the only Indian paper in *Journal of Cell Biology* originated from the University of Hyderabad. The Indian Statistical Institute provided the only Indian paper in *American Journal of Human Genetics*. Considering the large number of people engaged in new biology research in India, this infrequent use of high impact journals is disconcerting. Throughout the three years studied, as seen from *BIOSIS*, no Indian researcher published a single paper in *Science*, the weekly journal of the American Association for the Advancement of Science. Sadly, more than 46.4% of India's work indexed in *BIOSIS* 1992–1994 appeared in journals not indexed in *SCI*, and another 37.4% of papers appeared in journals with impact factor below 1.0. The silver lining to the cloud is provided by a few lesser-known institutions publishing papers in some better-known journals, for example, a paper in *Lancet* from Dharbhanga Medical Hospital, and another in *Nature* from Utkal University.

A few well-meaning scientists are worried that studies such as this might encourage Indian scientists to publish their work in foreign journals to the great detriment of national initiatives to publish quality journals. While I appreciate their concern, I believe that without a large number of Indian scientists and institutions performing first-rate work we cannot sustain the quality of our journals for long. Remember the US was on the periphery of European science in the early decades of the century, but today the US is the centre in virtually every field of science and technology, and most leading journals are published in the US. It would be educative to examine this transformation as Valiathan[24] proposed, in a different context in his A. L. Mudaliar lecture at the University of Madras more than a decade ago. In his example, in the early part of the century, students of surgery from both India and the US went to Great Britain to hone their skills. According to Valiathan, most Indians returned and set up lucrative practice, whereas the Americans went home, built institutions and transformed their country into the world leader in surgery.

Clustering of institutions

I have mapped the contributions of major publishing institutions to often-used journals and to different sub-fields in the form of matrices (not shown here). From these matrices, one can gain an insight into the cognitive profile – areas of publishing activity – of an institution. For example, NII is strong in immunology, biochemistry and molecular biology, genetics and biophysics. IISc has many papers in biochemistry and molecular biology and biophysics, and a small number of papers in plant sciences, microbiology, genetics, immunology and biotechnology. Besides, IISc has 18 papers in journals grouped under biology and 23 papers in multi-disciplinary journals (such as *Nature*, *Proceedings of the National Academy of Sciences USA* and *Current Science*). For a rigorous analysis, one needs to classify these papers into appropriate sub-fields. From Table 11 and these matrices, one can see that a cluster of institutions working on classical biology and agriculture concentrate on certain sub-fields and publish often in journals of low impact, and another smaller cluster of institutions working on new biology publish part of their papers in high-impact journals. For example, IISc, University of Delhi, Aligarh Muslim University, NCL, Indian Institute of Chemical Biology, CCMB, University of Madras and NII publish often in biochemistry and molecular biology, whereas the agricultural universities concentrate on agriculture, plant science, zoology, entomology, etc. It would be useful to investigate this phenomenon in detail and to examine the cognitive cross-links between institutions in the two clusters. I believe it would be in the nation's interest if the same set of practical problems were tackled both by classical biologists in the larger cluster and the new biologists in the smaller cluster, and if researchers enter into a dialogue across the cluster boundary. At the moment, there seems to be very little overlap between the interests of the two, and one hardly sees joint efforts involving institutions across the cluster boundary. Funding agencies such as DST and SERC might wish to encourage such collaborations.

Conclusions

BIOSIS is a good source of information on India's contribution to life science research. It covers all areas of life sciences, viz. classical and new biology, agriculture and some areas of medicine. In addition, from a bibliometrician's point of view, *BIOSIS*, like *SCI* and *Mathsci*, is easy to work with. Journal titles are given in full, and journal country information is provided in the print version of *Serial Sources*. The one apparent lacuna

Table 12. Per cent of internationally co-authored scientific and technical papers for selected countries, by field, 1991–1995 (ref. 1)

Field	World	India	USA	UK	Germany	France	Israel	Japan
All S & T fields	13	13	16	26	30	32	37	13
Clinical medicine	10	11	12	18	21	22	23	11
Biomedical research	14	13	17	29	35	32	42	16
Biology	11	15	13	25	26	28	33	12
Chemistry	11	8	14	25	23	28	39	8
Physics	19	20	25	40	43	45	51	15
Earth and space sciences	20	21	24	43	52	51	46	32
Engineering and technology	11	12	14	20	22	27	36	12
Mathematics	19	31	24	36	36	29	55	19

Source: *Science and Engineering Indicators 1998*, NSF, based on the 1981 ISI constant journal set of about 4,800 journals.

is that it indexes less than 120 Indian journals, although Insdoc's *Directory of Indian Periodicals* lists several hundred under biology, life sciences, medicine and agriculture. Considering that *BIOSIS* is an international database with a mandate to cover the entire world's literature output, one cannot find fault with the decision not to index more than about 120 Indian journals. The poor quality content of many Indian journals and delays in publication also do not help. Some other international databases index even fewer Indian journals. For example, *SCI*, which cares for quality of contents, indexes about a dozen Indian journals, and *Medline* about 25. Another lacuna is that *BIOSIS* has indexed certain journals either in 1992 or in 1993–1994, but not in both periods. Even journals like *Indian Journal of Biochemistry and Biophysics* and *Journal of Biosciences* have suffered.

Life science research in India is much larger than physics research. There are about 4,100 to 4,300 papers from India indexed in a year's *Physics Abstracts* (or *INSPEC–Physics* CD), compared to about 7,000 in *BIOSIS*. Although this large volume can be attributed in part to the coverage of the literature of agriculture and medicine in *BIOSIS*, the fact is there are more biologists than physicists in India, a very large proportion of them working in classical biology. Enrollment figures and the number of doctoral dissertations submitted every year will bear this out. This analysis shows that more than 55% of Indian papers indexed in *BIOSIS* are published in Indian journals. One reason is that a substantial percentage of Indian papers in life sciences concern agriculture and most of it is published in Indian journals (including animal and veterinary science, horticulture and forestry). The extent of use of local journals varies from field to field. My analysis of agricultural research in India, based on *CAB Abstracts* 1990–1994, showed that close to 77% of papers were published in Indian journals[11]. Corresponding figures for other fields are as follows: 35% in mathematics, based on an analysis of *Mathsci* 1988–1995 (ref. 7); 18.3% in physics, based on *INSPEC – Physics* 1992 (ref. 9); 9.5% in materials science, based on *Materials Science Citation Index* 1991–1994 (ref. 8); 33.5% in medicine, based on *Medline* 1988–1994 (ref. 10).

A very large proportion of Indian life science papers are published either in low-impact journals (impact factor less than 1.0) or in journals not indexed in *SCI*. According to Veena Parnaik from CCMB, one reason for the relatively poor quality of Indian research papers in life sciences, is the relatively poor quality of biological education in schools and colleges, which cannot be easily set right at the Master's level. The training in physics and chemistry is somewhat better, says Parnaik. Less than 1.0% of Indian papers have appeared in journals with an impact factor higher than 4.0. That only a very small percentage of Indian papers are published in high impact journals is not unique to life sciences. Indeed, an even smaller percentage of papers become well-cited.

What should be of concern to policy makers and funding agencies is the fact that even scientists from better-known institutions publish a large number of papers in journals not indexed in *SCI*. For example, 20 of the 224 papers from IISc, 13 of the 120 papers from NII, 6 of the 86 papers from CCMB, 96 of the 216 papers from Central Drug Research Institute, and 37 of the 173 papers from Bhabha Atomic Research Centre have appeared in non-*SCI* journals. Some of these appeared in Indian journals such as *Indian Journal of Experimental Biology* (which was indexed in *SCI* a few years ago but was dropped), *Journal of the Indian Institute of Science, Indian Journal of Physiology and Allied Sciences, Indian Pediatrics,* and *Bulletin of the Postgraduate Institute of Medical Education and Research Chandigarh.* It is also possible that a few papers from India might have appeared in journals which are new and therefore not yet listed in *JCR*. The least that Indian life scientists could do is to avoid publishing their work in non-*SCI* journals and strive instead to build up Indian journals.

Academia accounts for a very large percentage of India's publications, although one is painfully aware of the tremendous state of neglect of most of India's higher educational institutions. This is due to the large number of doctoral students, who are keen to finish their work quickly and publish it in the best possible journals.

Literature-based mapping can provide valuable insights for science-policy makers. It can reveal a nation's (or any large aggregate's) strengths in terms of journals used for publishing, active institutions and sub-fields. This study is an analysis of publications only from a single database. One could extend this by consulting more databases, looking at actual citations to Indian papers (instead of being content with the impact factors of journals, as done here), and by looking at the extent and impact of collaboration, both national and international. I have presented some comparative data on the distribution of papers in different fields in Table 2 and the extent of international collaboration in Table 12. It would also be useful to look at the anatomy of the performance of different institutions, in conjunction with data on funds received for research by different investigators. I hope to look at these issues in the near future.

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Ecological niches and amplitudes of rare, threatened and endemic trees of Peppara Wildlife Sanctuary

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Identification and documentation of rare, threatened and endemic species is important in the conservation of biodiversity. These species usually have specific ecological niches, edaphic gradients, and vulnerable habitats. In the present study, habitats of Peppara Wildlife Sanctuary were analysed for ecological niches and amplitudes of rare, threatened and endemic tree species by stratified random sampling techniques. The study resulted in documenting 151 tree species belonging to 51 families with 62 endemics (41% of endemism), 6 rare and 8 threatened species.

INDIA has been identified as one of the top 12 mega-diversity countries of the world. Among the 18 hot spots recognized in the world, two are in India–Eastern Himalayas and Western Ghats[1]. The Western Ghats, which is one of the nine biogeographic regions of India possess various types of tropical forests, ranging from wet evergreen to dry deciduous. Nearly 63% of the tree species of the low and the medium elevation evergreen forests of Western Ghats are endemic[2]. This high level of diversity and endemism in the Western Ghats has conferred on them the hot spot[1,3] status. Nayar[3] has identified three endemic centres in Kerala–Agasthyamalai, Anamalai high ranges and Silent Valley–Wynad. IUCN (ref. 4) has identified Agasthyamalai and its environs as one of the three centres of plant diversity within India.

Agasthyamalai ranges, a compact block of hills situated at the southernmost end of the subcontinent has one of the richest flora in the Western Ghats. It is also one of the important centres of plant speciation. Many plants new to science have been discovered and described from Western Ghats, most of them either being narrow endemics[5] or are with limited range. Extremely restricted areas have been reported as type localities for a number of species of plants, many of which are endangered or rare[6]. For example, Chemmunji peak area in the Agasthyamalai range is the type locality for half a dozen endemic species. The study area, Peppara Wildlife Sanctuary, selected for the present work comes under Agasthyamalai range. A detailed study of endemism in the Western Ghats is necessary to define the priorities in conservation policy[7].

One of the challenges of the conservation of rare, threatened and endemic plants is the identification of their ecological niches and the amplitude of distribution. Niches are defined as a cell of the multi-dimensional space formed by the environmental variables within which a particular species will always be found[8]. Ecological amplitude is the capability of a species to establish in various habitats lying along an environmental gradient. A species showing very low ecological amplitude has localized distribution because of the narrow range of conditions on which their growth depends. These species are called 'habitat specialist' because they have a significant positive association with their habitat or they cannot survive outside of their habitat[9].

In order to categorize threatened species, IUCN (ref. 10) has updated the categories on the basis of geographical range, population and fragmentation. The threatened species categories now used in the Red Data Books and the Red List are critically endangered (facing an extremely high risk of extinction in the wild in the immediate future), endangered (not critical, but facing a very high risk of extinction in the wild in the near future), and vulnerable (not critical or endangered but facing a high risk of extinction in the wild in the medium-term future). Taxa listed as critically endangered qualify for vulnerable and endangered, and those listed as endangered qualify for vulnerable. Together these categories are described as 'threatened'.

A rare species is one that occurs in widely separated small sub-population so that inter-breeding between sub-populations is seriously reduced or restricted to a single population[11]. They are not at present endangered or vulnerable but face a high risk of being so and usually localized within restricted geographical areas or habitats or are thinly scattered over a more extensive range[12]. A hypothetical rare species is one with narrow habitat range, low climate tolerance, specialized adaptation requiring an outside agency for pollination, poor dispersal strategies, few seeds per fruit and poor viability of seeds[3].

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The spatial distribution of plants and location, their degree of habitat niche specialization and the spatial distribution of sensitive habitats are some of the major aspects to be analysed. It is relatively straightforward to classify species by their distribution among habitats defined by fixed topographic or edaphic features of the plot[13]. Most of the endemic species with a small geographic range end up as rare species and later threatened species unless their habitat is protected[3]. The present paper attempts to study the rare, endemic and threatened trees, their ecological tolerance, distribution, ecological niches and the spatial distribution of niches.

Study area

The study area forms a part of the Trivandrum district in Kerala. The area is enclosed within 8°34′30″ to 8°41′25″N. latitude and 77°06′50″ to 77°14′05″E longitude (Figure 1). The entire area lies within the catchment area of the Karamana river (Karamanayar) which originates from the slope of Chemmunjimottai, the highest peak of the sanctuary (1717 m). The terrain is undulating with elevation ranging from 100 m to 1717 m. The maximum mean daily temperature during March, the hottest month, is 32°C while it is 20°C in January, the coldest month. The mean annual rainfall is 320 cm (ref. 14). The area of the sanctuary is 75 km^2 and is covered by tropical and montane subtropical forests.

Methodology

The following forest types were identified based on Champion and Seth[15]: southern hilltop tropical evergreen forest, west coast tropical evergreen forest, west coast semi-evergreen forest, pioneer euphorbiaceous scrub, southern secondary moist mixed deciduous forest, *Myristica* swamp forest, submontane hill valley swamp forest, riparian fringing forest, southern subtropical hill forest and *Ochlandra* reed brake. Stratified random sampling technique was used for sampling. 0.1 ha plots were selected from each forest type for detailed investigation. A total of 2.1 ha area was sampled and all tree species above 10 cm DBH were enumerated. Materials collected were identified and analysed using relevant literature, monographs and taxonomic revisions[3,7,16]. Confirmation of identification was done by matching the specimens with authenticated specimens available at the Kerala Forest Research Institute's (KFRI) herbarium.

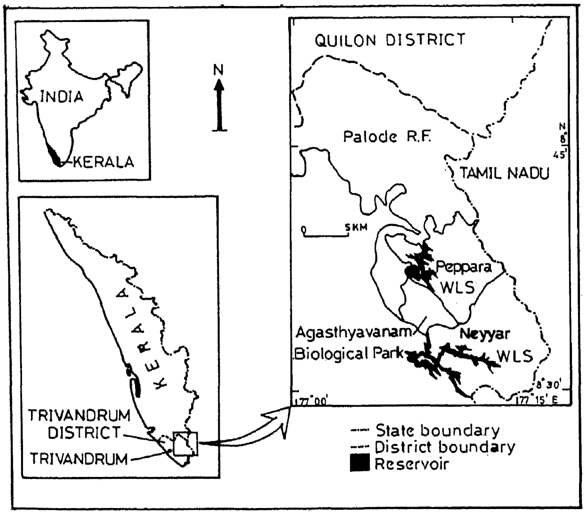

Figure 1. Location of the Peppara Wildlife Sanctuary.

Results and discussion

Of the 151 tree species spread over 51 families, 62 species show endemism, (41%). A high degree of endemism is seen in the endemic forest type of the Western Ghats, i.e. *Myristica* swamp forest (61.11%). West coast evergreen forest comes next followed by southern hilltop tropical evergreen forest and riparian fringing forest (Table 1). The number of endemics is greater in the climax forests than in the secondary or derived ones, thereby accounting for the low percentage of endemism in the southern secondary moist mixed deciduous forest (10.25%) and pioneer euphorbiaceous scrub (23.80%). The high degree of endemism in the evergreen forests of the Western Ghats can be attributed to the isolation of the ghats from other moist formations and the prevailing drier climatic conditions in the surrounding areas[17]. *Myristica* swamp forest (57.60) and hilltop evergreen forest (57.04) show higher densities of endemic species while the density is low for southern secondary moist mixed deciduous forest (2.76). The hilltops in the Western Ghats in particular, harbour a high percentage of endemics because they act like 'islands amidst islands'. This isolation has facilitated the process of speciation leading to a phenomenon of 'vicarance' between sister species derived from a common ancestor, one of which thrives in the evergreen forests of the ghats and the other in the adjacent dry regions[7].

Of the 62 endemic tree species, *Mesua nagassarium* occurs in 7 forest types and *Actinodaphne bourdilloni, Artocarpus hirsutus, Holigarna arnottiana* and *Vateria indica* in 6 of them (Table 2). This indicates that these species have high ecological amplitude and niche overlap. 32 species exhibit narrow ecological tolerance with a high degree of habitat specialization with 25 species among them exhibiting very low relative densities. Of the endemic species, *Mesua nagassarium* shows highest density (5.24), followed by *Holigarna arnottiana* (2.73), *Knema attenuata* (2.61), and *Vateria indica* (2.25).

Table 1. Total no. of species (T.Sp.), no. of endemics (NE), percentage of endemics (PD), relative densities of endemic species (RD) in forest types and no. of endemic habitat specialists (HS)

Forest type	T.Sp.	NE	PD	RD	HS
Southern hilltop tropical evergreen forest	27	12	44	57.04	3
West coast tropical evergreen forest	71	36	50.70	45.58	14
West coast semi-evergreen forest	68	27	39.70	36.57	7
Pioneer euphorbiaceous scrub	21	5	23.80	15.59	1
Southern secondary moist mixed deciduous forest	39	4	10.25	2.76	1
Myristica swamp forest	18	11	61.11	57.60	1
Sub-montane hill valley swamp forest	23	6	26.08	18.85	0
Riparian fringing forest	48	21	43.75	48.45	2
Sub-tropical hill forest	44	19	43.18	31.71	3

Table 2. Rare, threatened and endemic trees of Peppara Wildlife Sanctuary

				Relative density of species in forest types						
Endemic species	AD	HE	EG	SE	PE	MD	MS	SP	RF	SH
Actinodaphne bourdillonii Gamble	1.64	3.92	0.77	1.83	5.19				0.53	2.59
Actinodaphne campanulata J.HK. *var. obtusa* Gamble	0.16									1.52
Actinodaphne malabarica Balak.	0.20				1.30				0.51	
Actinodaphne salicina L.	0.21	1.96								
Aglaia elaeagnoidea (Juss). Benth *var. bourdillonii* (Gamble) Nair	0.33		0.30							
Aglaia minutiflora Bedd.	0.02									0.26
Allophylus serrulatus Ra.	0.15			0.34					1.05	
Arenga wightii Griff.	0.01		0.13							
Artocarpus hirsutus Lam.	1.42		0.38	2.85	3.90	0.42		1.45	3.79	
Atlantia wightii Tanaka	0.01		0.17							
Baccaurea courtallensis (Wight) Muell.-Arg.	0.03			0.34						
Bentinckia condapanna Berry *ex* Roxb.	0.01									0.09
Buchanania lanceolata Wight	0.01			0.16						
Canthium pergracilis Bourd.	0.07		0.69							
Calophyllum apetalum Willd.	1.87		1.70	0.74			5.77		8.44	0.26
Cinnamomum malabatrum Burm. f.	0.04					0.37				
Cinnamomum travancoricum Gamble	0.05									0.52
Cleistanthus travancorensis Tablonzky	0.01			0.12						
Cullenia exarillata Robyns	1.24		5.18							6.01
Diospyros candolleana Wight	1.78	6.86	5.38	2.62					0.53	0.63
Diospyros paniculata Dalz.	0.01		0.14							
Dipterocarpus bourdilloni Brand.	0.23		1.46	0.37						0.26
Elaeocarpus munronii (Wight) Mast.	0.69								1.02	5.20
Euodia lunu-ankenda (Gaertn.) Merr. *var. tirunelvelica* Henry and Chandr.	0.14				1.30					
Garcinia gummi-gutta (L.) Robs.	0.28		1.76	0.26					0.57	
Gluta travancorica Bedd.	1.51	2.94	2.07	3.46					5.17	
Gordonia obtusa Wall. ex Wight and Arn	0.03		0.30							
Goniothalamus rhynchantherus Dunn	0.08		0.77							
Holigarna arnottiana J.HK.	2.73		2.25	2.10			7.69	7.25	4.40	0.92
Hopia parviflora Bedd.	1.91			2.69		0.33		4.35	8.56	1.26
Humboldtia vahliana Wight	0.41		2.72						1.02	
Hydnocarpus macrocarpa (Bedd.) Warb.	0.08								0.51	0.26
Hydnocarpus pentandra (Buch.-Ham.) Oken	0.56	2.94		2.12						
Hymenodictyon obovatum Wall	0.02								0.21	
Kingiodendron pinnatum (Roxb. *ex* DC.) Harms.	0.04		0.38							
Knema attenuata (Hook. f. and Thoms.)	2.61	0.98	2.02	2.01			15.3		3.26	
Lagerstroemia microcarpa Wight	0.34		0.24	0.68		1.64			0.53	
Chionanthus leprocarpa Thw.	0.05								0.51	

contd...

Table 2. *contd...*

Var. courtallensis (Bedd.) K. K. Nair										
Litsea glabrata Hook. f.	0.02	0.21							0.51	
Leptonychia moacurroides Bedd.	0.02			0.26						
Litsea ligustrina (Nees) Hook. f	0.02		0.24							
Litsea oleoides (Meissn.)	0.10	0.98								
Mangifera indica L.	0.23		0.30	1.26					0.53	
Mastixia arborea ssp. meziana (Wang.) Mathew	1.17	0.98	0.85				1.92	2.90		3.
Meiogyne pannosa (Dalz.) Sinclair	0.07		0.69							
Mesua nagassarium (Burm. f.) Kosterm	5.24		3.16	5.42	3.90		1.92		1.57	4.
Milisua wightiana Hook. f. and Thomas	0.02			0.19						
Myristica fatua Houtt. var. magnifica (Bedd.) J.	0.64						5.77			
Myristica malabarica Lam.	1.26		0.30				9.62	1.45		
Ormosia travancorica Bedd.	0.03		0.30							
Palaquium ellipticum (Dalz.) Baillon	0.32		1.03				1.92			
Pinanga dicksonii (Roxb.) Blume	0.01		0.16							
Poeciloneuron indicum Bedd.	0.21	0.98	0.30	0.37						0.26
Pterospermum rubiginosum Heyne ex Wt. and Arn	0.08			0.74						
Scolopia crenata (Wt. and Arn.)	0.32			1.02			1.92			
Semecarpus travancorica Bedd.	0.08		0.73							
Spondias indica (Wt. and Arn.) Airy shaw and Forman	0.16		0.24	0.71					0.51	
Symplocos macrocarpa Wt.and Cl. *ssp. kanarana* (Talbot) Noot.	0.09		0.60	0.26						
Syzygium mundagam (Bourd.) Chitra	1.17	3.92	2.37	2.12			1.92			0.26
Syzygium occidentalis (Bourd.) Gandhi	0.03		0.30							
Vateria indica L.	2.25		5.20	1.53			3.85	1.45	5.76	2.50
Vernonia travancorica Hook. f.	0.57	4.90								0.31

R, Rare; T, Threatened; AD, Mean densities; HE, Southern hilltop evergreen forest; EG, West coast evergreen forest; SE, West coast semi-evergreen forest; MD, Secondary moist mixed deciduous forest; SP, Sub-montane hill valley swamp forest; PE, Pioneer euphorbiaceous scrub; MS, *Myristica* swamp forest; RF, Riparian fringing forest; SH, Subtropical hill forest.

Among the forest types, west coast evergreen forest has the maximum number of habitat specialists (14), followed by the west coast semi-evergreen forest (7). The rest show a comparatively low number of endemic species. The high degree of habitat specialists in west coast evergreen and semi-evergreen forests show the unique specialized niches (which provide particular growth factors due to microclimatic and edaphic conditions) and microclimatic conditions (regional difference in temperature, moisture and other factors due to topographic features[18]) prevailing in these forests. When compared to the percentage of endemic plants (41%) to their relative densities they show low representation of densities of endemic species. Of the 62 endemic species, the genus *Actinodaphne* comprises the highest number of species (4) followed by *Litsea* (3). *Aglaia, Cinnamomum, Diospyros, Hydnocarpus, Myristica* and *Syzygium* have two endemic species each. Among the 51 families, 8 have 40% or more endemic species with Dipterocarpaceae having 100% endemism (Table 3). Within the ghats, the variation in the degree of endemism is mainly determined by: (i) the increasing number of dry months from south to north, and (ii) the decrease in temperature with increase in altitude. These two gradients also explain the numerous cases of vicariance encountered within the evergreen continuum. Local topographic varieties add another dimension to the floristic diversity and endemism. In this region, climatic shift is more rapid due to the foehn effect and to the gradual transformation in the rainfall pattern from the south–west monsoon regime (with a peak in July) to the two peak regime characterized by the dominance of rains during the north-east monsoon from October to December[6].

Table 3. Families with 40% or more endemism

Family	No. of species	No. of endemics	Percentage of endemism
Dipterocarpaceae	03	03	100.00
Lauraceae	11	09	81.81
Clusiaceae	05	04	80.00
Ebenaceae	03	02	66.66
Anacardiaceae	10	06	60.00
Myristicaceae	05	03	60.00
Flacourtiaceae	05	02	40.00
Myrtaceae	05	02	40.00

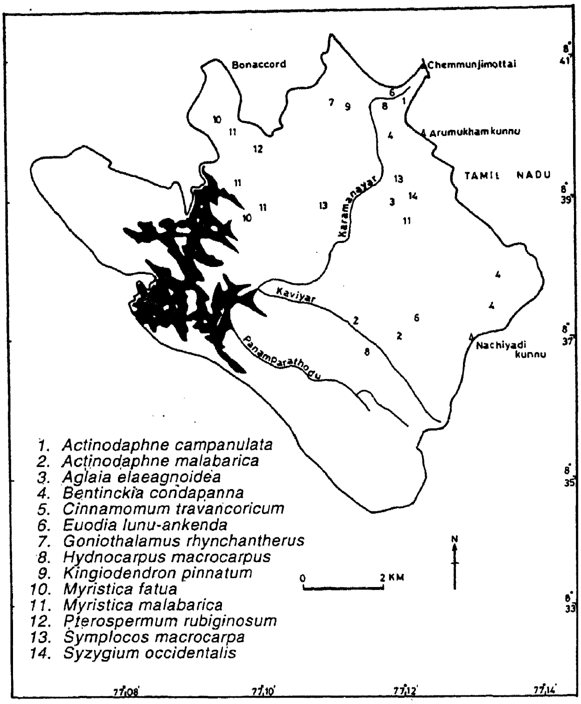

Figure 2. Distribution of rare and threatened trees in Peppara Wildlife Sanctuary.

The subtropical hill forest exhibits the highest number of threatened species (3) but with a very low density of species. The west coast evergreen forest shows 3 rare and 2 threatened species with good densities. Very high relative densities are exhibited by the threatened species of *Myristica* swamp forest (15.39). The derived secondary moist mixed deciduous forest lacks rare and threatened species. A total of 8 (5.29%) threatened species are recorded from the study area. There are 6 rare (3.97%) species also. The approximate location of the rare and threatened species is given in Figure 2. The location is the quadrat of occurrence of the rare and threatened species gathered using Global Positioning System (GPS). The relative densities of rare and threatened species exhibit low values as endemic species, i.e. 0.92 and 2.77, respectively. All rare and threatened trees are endemic and most of them are confined to the southern parts of the Western Ghats.

Conclusion

The foremost task in the conservation process is to rate different protected areas for their holdings of rare, threatened and endemic species. The article gives basic knowledge about documentation of niches and amplitude of rare, threatened and endemic species in a regional scale. This documentation can help locate areas and habitats of high concentration of these species so that critical habitat/habitat sites would get priority for conservation.

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Perspectives on energy R&D and next generation technologies*

Arcot Ramachandran and J. Gururaj

Energy and environment challenges during the next two decades will to a large degree determine sustainable development, environmental quality and energy security. Energy strategy usually embodies various aspects of policy and technology pathways. The challenge is to focus R, D & D on technologies that seek to achieve higher levels of efficiency covering all forms of energy conversion as well as those that seek to improve the efficiency of energy conversion at the end use stage. The paper presents the technology pathways highlighting those that are needed for a secure energy future, at the same time managing the environmental impacts including the global climate change concerns.

ENERGY and environmental issues are no longer peripheral among the aims of a national technology policy. We are on the threshold of entering a new millennium facing even greater challenges than before. The way we address the energy and environmental challenges of the next two decades will, to a large degree, determine sustainable growth, environmental quality, and national security. Energy research and development have received scant attention in the discussions of a national technology policy over the last decade and a relatively small share of the national R&D budget. It is therefore not surprising that the performance of our country's energy sector has been rather poor resulting, among others, in unreliable quality and unsatisfactory power supply situation.

Admittedly, energy sector reforms are urgently needed to rectify the supply–demand imbalances, inefficiencies and inequities in the urban and rural energy systems. Nevertheless, I believe that as a nation we have some critical choices to make with respect to our long-term strategy for inducting the next generation of energy technologies.

Population growth, economic and industrial development, and technological change drive energy needs. To examine the energy technology pathways, one needs to consider perspectives on energy that take into account the inter-connections between global and national actions on the one hand and between different economic sectors at the national level on the other. Exciting technological developments are taking place as a result of growing concerns about the environment and sustainability. Successful application of new technologies can fundamentally change the way energy is produced and utilized.

In today's world, perceptions about the crisis that engulfed the energy sector in the seventies and eighties have considerably changed. What was once a major concern that oil resources will get depleted in the near future and prices would drastically increase was belied by the changed situation in global oil supply and demand and new discoveries. The oil prices have been relatively stable since mid-eighties and, in fact, oil price in real terms is perhaps even lower than what it was before the oil crisis. This rather anomalous situation has lulled many economists and energy industry leaders into a sense of complacency. I strongly believe that we can ill-afford this complacency as also the lack of concern for the long-term outlook. I will revert to this issue later.

In the last two decades, despite soft conditions in the oil front, profound changes have taken place worldwide in terms of wide-ranging reforms in the energy sector, especially in the electric power sector, including privatization, deregulation, pricing policies, environmental regulations etc.

In India too, economic liberalization and opening the doors for private sector participation were expected to attract investments in energy, but the impact of private sector on energy sector development has not been significant so far. As a matter of fact, energy sector investments from both public and private sector have been woefully inadequate, as evidenced in major shortfall in capacity addition especially in the power sector. One of the consequences of this situation is that the thrust of R&D has lost its edge and whatever momentum existed earlier has slackened. If the demand for increasing the

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quantity and quality of energy services in our economy is to be managed, it is imperative to ensure strong support to R&D so that the critically needed high rate of innovation takes place.

Worldwide, economic growth has largely been associated with increased energy consumption, and increased use of energy has led to more urban air pollution, contaminated water, social disruption, and massive emission of greenhouse gases. Recent events in some countries indicate that the link between economic growth and energy consumption can be broken by pursuing efficient production processes and by reducing waste. At the same time the link between energy consumption and pollution can also be broken by relying more on renewable energy as well as efficiently using fossil energy. Only by doing so can we expect to have less energy intensive growth as well as growth with less pollution. Of course, there is almost always a trade-off to be made on the basis of how costs and benefits are assessed to arrive at rational choices.

The energy debate at the global level is replete with a variety of contentions and differing viewpoints. By and large, the issues involved relate to climate change concerns and energy for sustainable development. Discussions at various global forums promise to open the door for agreements on what is called Clean Development Mechanisms (CDM). Without going into details of the positions taken by different groups of countries, suffice it to say that global agreements being forged will have a profound impact on the future technological pathways for all countries. A defining challenge for the next century is how to effect a progressive shift toward an economically, environmentally, and socially more sustainable course.

Historically, transition from one generation of energy technologies to the next has been taking place at intervals extending over 4–5 decades. In this context, an interesting observation made by IIASA some time ago concerns the progression of the world energy system during the last two centuries towards fuels having higher hydrogen to carbon ratio. For instance, in 1800, the global primary energy consumption had a H/C ratio of about 0.2 (note than H/C ratio of wood is about 0.1). By 1900, this had increased to 0.8 with progressive inroads made by coal (H/C ratio approximately 1). By 1950, this had further increased to 1.3 with oil (which has a H/C ratio of approximately 2) forming a significant part of the energy mix. By 2000, the H/C ratio will be closer to 4, indicating the increasing role of natural gas (methane H/C = 4). Beyond 2050, the likelihood of a hydrogen economy taking roots is strongly indicated. In line with this trend by the 22nd century we may witness a non-fossil fuel hydrogen economy. In each era, new sources never completely replaced the earlier ones. Therefore one can say that the future mix of energy technologies is likely to reflect this trend.

In India, energy has remained a major constraint for our country's socioeconomic development. The challenge that we face today is twofold, while one is concerned with what we can and should do in the near term to improve the poor state of energy services available to industry, agriculture, household and commercial sectors through policy and institutional reforms and efficiency measures, the other concerns the issue of deciding on what investments are needed to build our scientific and technological capacity so as to induct the next generation of energy technologies.

India is the fifth largest energy consuming country of the world. It imports 60% of its oil needs and is the third largest oil importing country in Asia, after Japan and Korea, with an annual volume of around 40 million tonnes and this amount is increasing inexorably. The oil crisis of 1973, 1979 and the Gulf crisis of 1991 did have an adverse affect on our economy. If we are truly strategic in our approach, we should build and maintain emergency oil stocks, taking advantage of low oil prices of the kind that occurred during this year when oil prices dipped below $10 per barrel. Needless to say that this will require political will of a high order.

Our country has the largest unsatisfied demand for natural gas in the world. The demand is to supply ratio based on present reserves is of the order of 2.5 to 1 for the year 1999 which is expected to increase to 4 to 1 in 2010 (from 143 to 58 MMSCMD in 1990 to 265 to 68 MMSCMD in 2010). Domestic availability can be increased by intensifying exploration, improving R/F, and using unconventional gas resources namely, coal bed methane, hydrates and coal gasification.

The need for gas imports appears inevitable. In the medium term import from Myanmar (28–42 MMSCMD) and in the long term from Oman (56 MMSCMD), Iran (50–75 MMSCMD) and Central Asia (30 MMSCMD) through pipelines must be initiated. LNG imports from Oman, Qatar, Indonesia, Malaysia, and Australia totaling over 40 MM TPA are envisaged during the next five years. Increased use of natural gas in combined cycle power plant deserves serious consideration, as this is one of the most efficient technologies for power generation with greatly reduced emission of carbon dioxide.

We have in the country huge reserves of coal and lignite, of the order of 230 billion tonnes (80 billion tonnes proven) of which 300 million tonnes were mined last year. However, a vast majority of our coal reserves are of very low grade, with more than 40% mineral matter (ash) content which results in difficulties in handling, transporting, and using coal for power generation. This disadvantage is mitigated to a considerable extent by the fact that the sulphur content of coal is generally less than half per cent resulting in lower amounts of sulphur dioxide emission to the environment. The challenge that this coal poses to clean thermal power generation is through modifications and improvements in the conventional technologies, development and adoption of new technologies; with efficiency and environment being controlling factors.

There has been no dearth of studies on how to deal with India's energy problems. Studies by various committees – Energy Survey Committee (1965), Fuel Policy Committee (1973), Energy Policy Committee (1979), Advisory Board on Energy (1984), and other studies by the Planning Commission, TERI, CII, FICCI, ASSOCHM, TIFAC – have all analysed the evolution of energy demand and supply, the situation of energy in rural areas, energy resources, investment requirements and policy options. Regardless of the deviation between projections made in these studies and actual reality, it is clear that the issues involved are quite complex and that policy and technology choices will have to be made keeping in view both short- and long-term perspectives.

Energy strategy usually embodies various aspects of policy and technology pathways and therefore it seems appropriate to revisit the strategy for effecting improvements and for charting new pathways, wherever possible. The challenges to be faced in our energy strategy are how to reconcile energy supply with increase in its demand, finance the power sector expansion, increase domestic oil and natural gas production, develop alternative sources of energy and manage the environmental impacts including the global climate change. Improving the environmental conditions in both urban and rural areas has become a dire necessity when we look at our continuously deteriorating environmental quality. Measures such as fuel switching, energy conservation and deployment of energy-efficient and environmentally sound technologies must receive much greater attention than heretofore. Prices must reflect full economic costs and only then will there be necessary signals to producers and consumers alike to use energy more efficiently.

I wish to focus attention here mainly on the technology dimensions of our energy strategy.

Attempts to chart technology pathways for the country indeed started as far back as 1973 when the erstwhile NCST undertook assessments of technologies and recommended R&D efforts in the short, medium and long term periods. The NCST played a useful role in catalyzing the establishment of new programmes in the then Department of Science and Technology like New Energy Sources, Ocean Science and Technology, Environment, Biotechnology, NRSA, NISSAT, TIFAC etc. which were subsequently spun off into new institutional arrangements including new government departments and ministries. The scientific and other professional communities have made notable contributions in all these areas.

Our scientific and technical communities have amply demonstrated their abilities to produce results when the nation sets clear goals and backs them with sustained support. The country can meet much of its growing demand for energy services in a less capital-intensive and less environmentally harmful manner by making bold and imaginative choices out of the vast array of cost-effective and energy-efficient technologies. In examining technological pathways and in making choices, it is important that a distinction be made about what is feasible in the short term and what lies in our long-term interest.

India's existing energy sector technology base is vast and varied. Some of its capital stock are old and replacements have not taken place. One of the dilemmas faced with regard to introducing new technologies is that life times of in-use energy capital stock are usually long and therefore this becomes a major consideration in replacing them in an economical way. Therefore, in the short term, one has to look for technology pathways that can improve the existing technologies. Costs can be minimized if efficient and cleaner technology replaces less environmentally friendly technologies at the time of capital stock turnover than through early turnover of stock. We have to keep in mind that other factors like market dynamics and user preferences also affect the extent to which this approach becomes feasible.

The challenge before the nation is to focus R&D on technologies that seek to achieve progressively higher levels of efficiency covering all the different stages and forms of energy conversion, as well as those that seek to improve the efficiency at the end use stage. Let me now briefly discuss technology pathways, highlighting those that I consider important for our energy future.

First, a word about government's role in supporting R&D. Given that large investments are needed to develop energy technologies which also usually require long gestation periods, government's facilitating role as well as support for R&D remains critically important. This is so despite structural changes in the energy sector with increasing private sector participation as well as competition and diversification of energy resources. From the long-term point of view, ensuring that sustained inputs become available for building the necessary scientific and technological capabilities, remains crucial.

A range of views exists regarding the future share of fossil fuels in primary energy supply. What seems indisputable however is that for the next couple of decades fossil fuels will continue to be a major player, coal will continue to be dominant in power generation, petroleum in transport, and natural gas will be gaining increasing share because of its inherent advantage as a clean fuel. Some long-term scenarios (for example, Shell International, IPCC etc.) postulate a rapidly increasing share of renewable technologies reaching up to 50% of the total by the middle of the 21st century.

Technology pathways must encompass the entire fuel cycle – exploration, extraction, refining, transport, conversion, transmission, distribution, and end use.

Technology opportunities in resource exploration have expanded with advent of new and advanced geophysical techniques that provide more precise information along with three-dimensional mapping, especially of oil and gas resources. Likewise in mining of coal or in drilling for oil, techniques involving inclined and horizontal drilling are proving to be more effective; other technologies of interest include deep drilling for onshore and offshore oil resources; reservoir modelling; enhanced oil recovery etc.

Coal will continue to remain as a major energy resource for our country. Technology opportunities in efficient utilization of our relatively low-grade coals must be pursued vigorously including beneficiation, coal briquetting, fluidized bed combustion systems, gasification including *in situ* gasification routes etc.

The issue of whether or not our coals should be beneficiated has remained unresolved for too long. It has taken almost 20 years for us to come to grips with the application of coal beneficiation technology whereas in other parts of the world it is almost a standard practice for a long time. Even now there are no clear guidelines or agreement among all concerned entities in the country on technological approaches to beneficiation. It is true that there are problems connected with the disposal of middlings and other environmental aspects. We must reach quick resolution of this issue and make appropriate technological choices. Transporting coal with 40% ash over long distances is an unnecessary wastage of energy. Moreover serious problems encountered in boilers, especially tube rupture, are attributable to the use of high-ash coals with high silica content. The technology of coal washing is well developed and therefore it must be introduced expeditiously. R&D in this area must focus on specific aspects of Indian coals. Research must also investigate dry and wet grinding of coal and transportation of coal water slurry. The technique of firing coal water slurry to substitute for oil firing must be established and inducted rapidly.

In all countries with significant use of coal, attention is increasingly turning to clean coal technologies. Despite its environmental limitations, coal will continue to be a major source of energy well into the next century. The importance of clean coal technologies for our country can hardly be overemphasized as nearly 70% of power generation is from coal.

It is imperative that R&D efforts be intensified for clean coal utilization technologies. Technology collaborations and joint R&D must be sought with outside partners wherever considered necessary in order to speed up their development and utilization in the foreseeable future. A variety of clean coal technologies for power generation are at various stages of development and deployment. Let me mention in passing, technologies that are commercially available and proven that we can rely on in the short term. These are, pulverized coal firing plant with flue gas desulphurization, NO_x and particulate emission control; atmospheric fluidized bed (AFBC) and circulating fluidized bed combustion (CFBC) plants.

The installed power generation capacity in the country has now crossed 90,000 MW and demand is growing at the rate of about 9% per annum. We must pay more attention to technological pathways for modernizing thermal power generation as it constitutes a major part of this capacity.

Pulverized coal technology is currently the mainstay of our thermal power generation. For large plants, this technology will continue for at least the next ten years. Currently, efficiency of coal power plants in our country is relatively low – in the range of 31–38%. The aim should be to progressively move towards a higher efficiency regime with proper choice of technologies. The successful experience with ultra-supercritical power plants in Europe with efficiency in the range of 45–47% at steam temperatures of 560–580°C, without reduction in availability, indicates the trend that need to be considered over the next 5–10 years. The main challenge in this case to overcome is the material problem. The most recently built pulverized-coal-fired power plant in Denmark uses special steels. In future plants, nickel base super alloys are likely to be used. The target steam temperature is 700°C and net efficiency between 52 and 55%. At least for the next 10–15 years, ultra-supercritical PF power plants will remain prominent.

Let me now turn to the next generation technologies for power generation which all aim at attaining higher efficiencies and lower emissions of CO_2 and other pollutants. These include: coal gasification and combustion of the synthesis gas in combined cycle gas turbine (integrated coal gasification and combined cycle – IGCC); pressurized fluid bed (PFB) in combined cycle; direct and indirect coal-fired turbines; fuel and pure oxygen gas turbines; magnetohydrodynamic generators; carboniferous fuel cells (molten carbonate, solid oxide); and separation of hydrogen from coal (hydrocarb process).

IGCC technologies have been developed in the United States and Europe, starting with a 30 MW gasification unit and subsequently upscaling it to 80 MW. Demonstration plants have helped to validate design features and to improve designs. The technology has reached a stage of technical readiness and is poised for commercialization. It is likely that this technology will take roots beyond 2005. PFB has also gone beyond pilot stage and is rapidly approaching the stage of commercial availability.

Our own efforts with regard to these technologies have been lacking in sustained support and commitment. For nearly two decades both BHEL, Trichy, and the Institute of Chemical Technology, Hyderabad, have been working on the development of coal gasification technology (fixed and moving fluidized bed) for power plant applications. BHEL has successfully operated a 6 MWe IGCC power plant. Presently a 150 tons/day plant is being operated for demonstration as well as for obtaining engineering data. Keeping in view the international developments as well as our own national experiences, efforts were made nearly a decade ago for setting up a 100 MWe IGCC plant. A detailed feasibility study was carried with the involvement of Bechtel and PDIL, Ranchi, and relevant technological plant engineering inputs were identified. It seems that the project has been languishing ever since, but recently another committee has recommended the establishment of a 250 MWe IGCC facility. Much time seems to have been lost in deciding on plant size, technology choice, location, and implementation arrangements. We need to be bold and decisive in moving fast on IGCC, as this will surely be one of the prominent next generation technologies for power generation.

In the seventies, spurred by the developments in the former Soviet Union, attempts were made to develop a coal-based MHD power plant. A 5 MWth MHD pilot plant was set up at BHEL, Trichy, in collaboration with Institute of High Temperature Physics, Moscow. While the feasibility was demonstrated, full-scale commercial plants proved elusive both due to anticipated technical problems as well as investment risks. Furthermore, the advent of natural gas combined cycle plants with comparable efficiencies but much lower investment cost has pushed the MHD technology out of contest at least in the foreseeable future. It is somewhat unfortunate that a number of spin-off technologies that resulted from MHD research have also remained unexploited even though many technologies such as high temperature air heaters, high temperature regenerative heat exchangers, oxygen-fuel combustion systems including combustion plasma systems, showed great promise.

In the long run, fuel cell technology for power generation seems to be the most attractive as it involves conversion of the chemical energy in the fuel directly into electricity. When it comes to very high net efficiency and minimum emission, the use of coal gas in fuel cells is particularly attractive, provided the exhaust gas of a high temperature cell is put to additional use in a downstream combined gas/steam cycle. Molten carbonate and solid oxide fuel cells are under development. Because these fuel cells operate at high temperatures (550 to 650°C for molten carbonate and approximately 1000°C for solid oxide) applications are likely to be mainly in industrial combined heat and power systems that require high-temperature heat for process use and in central station configurations. Very high efficiencies of the order of 75% are expected in such systems. Following the development of a molten carbonate fuel cell (MCFC) at the beginning of this decade, MITI in Japan is targeting at a 1000 MW pilot plant to be commissioned in early part of the next decade. However a breakthrough will have to be made with respect to service life and further cost reductions if the planning and construction of a MCFC demonstration plant is to be commenced in 2010.

Regarding other technologies, let me mention in passing that direct coal fired systems are in the prototype development stage and the Hydrocarb process is still at the proof-of-concept stage. Both hold considerable promise in the longer-term future.

In less than a decade, natural gas has emerged as an important fuel source for power generation. Natural-gas-based combined cycle power plant technology is not only readily available but is also proving to be attractive for quick capacity additions and at the same time is capable of meeting cost and environmental goals. Given the increasing availability of natural gas within the country as well as prospects of trans-boundary pipelines and LNG, we must intensify our effort on natural gas combined cycle plants as it is one of the most economical and environmentally attractive fossil fuel technologies. Its application is increasing because of its inherent advantages in terms of low capital costs and low emission. The most efficient units on the market achieve availability of 95% and 52% net efficiency. Further efficiency improvements by a few percentage points are expected in the next few years. Its attractiveness also stems from the fact that project gestation period is relatively short – about two years – and what is more is that plants can switch to fuel oil if it becomes necessary thereby giving considerable flexibility in fuel switching. From environmental standpoint it is surely a winner. Obviously this attractiveness is dependent on fuel availability and its price.

See Table 1 for comparison of various clean coal technologies.

All the different clean coal technology pathways have the common objective of utilizing the vast coal resources in an efficient, environmentally and economically acceptable manner as may be possible at any given time. We must keep our options open with regard to different clean coal technologies and prepare the ground for smooth transitions as and when it becomes expedient for achieving higher levels of efficiency, reliability, and environmental goals.

In order that we may develop our technological capabilities in these areas, we must have an action plan and mobilize support for its implementation. I shall now propose the outlines of such an action plan.

(i) Encourage the establishment of AFBC and CFBC power plants of commercially available unit sizes.
(ii) Facilitate the establishment of a PFBC power plant of 70–120 MWe for demonstration purposes as well as to advance development of high temperature and high pressure particulate control system.

Table 1. Characteristics of clean fossil electricity generating technologies (Nakicenovic[a], 1993) (all costs are in 1990 US dollars)

System	Units	Conventional coal	PFBC coal	IGCC coal	DCFT coal	ICFT coal	Combined cycle natural gas
Power	MW	400	400	1250	200	200	400
Capital cost	$\$/\mathrm{kW}$	1300	1750	1350	2100	1430	650
Fixed O&M cost	$\$/\mathrm{kW/yr}$	36.4	56	37.8	71.4	30	16.3
Variable O&M cost	$\$\mathrm{kW/yr}_e$	42.9	26.3	27.2	30.7	25.4	5.9
Efficiency	%	38.8	45	44.3	43.2	51.7	52.6
Fuel use	$\mathrm{BTU/kWh}_e$	8800	7600	7700	7900	6600	6490
Fuel cost	$\$/\mathrm{GJ}$	2.05	2.05	2.05	2.05	2.05	2.4
Life time	years	35	30	35	30	35	35
Load factor	%/yr	80	80	80	70	75	80
Cost (excl. fuel)	$\$/\mathrm{kWh}_e$	0.0229	0.0291	0.0218	0.04	0.0196	0.0094
Total ac electricity generating cost	$\$/\mathrm{kWh}_e$	0.0468	0.0486	0.0415	0.0608	0.0368	0.0265
Carbon emissions	$\mathrm{kgC/kWh}_e$	0.232	0.2	0.203	0.208	0.174	0.109

System	Units	MHD coal	MCFC coal	MCFC natural gas	SOFC coal	SOFC natural gas
Power	MW	150	650	200	165	165
Capital cost	$\$/\mathrm{kW}$	2600	1650	1150	1240	860
Fixed O&M cost	$\$/\mathrm{kW/yr}$	78	16.5	15	12.4	11.2
Variable O&M cost	$\$\mathrm{kW/yr}_e$	87.6	92	87.6	78.8	74.5
Efficiency	%	55	50.5	52.9	49.7	54.2
Fuel use	$\mathrm{BTU/kWh}_e$	6200	6750	6450	6860	6300
Fuel cost	$\$/\mathrm{GJ}$	2.05	2.05	2.4	2.05	2.4
Life time	years	30	30	30	30	30
Load factor	%/yr	70	75	75	75	75
Cost (excl. fuel)	$\$/\mathrm{kWh}_e$	0.0535	0.0313	0.025	0.0246	0.0197
Total ac electricity generating cost	$\$/\mathrm{kWh}_e$	0.0769	0.0564	0.0153	0.0484	0.0442
Carbon emissions	$\mathrm{kgC/kWh}_e$	0.163	0.178	0.108	0.181	0.106

PFBC, pressurized fluid bed combustion; IGCC, integrated gasification combined cycle; DCFT, direct coal-fueled turbines; ICFT, indirect coal-fired turbines; MHD, magneto-hydrodynamic; MCFC, molten carbonate fuel cells; SOFC, solid oxide fuel cells.

[a] Nakicenovie, N. *et al.*, *Energy*, 1993, **18**, 401–609.

(iii) Facilitate establishment of an IGCC power plant of suitable capacity (70–120 MW) based on fluidized bed gasifier technology for technology validation purposes and to obtain data on technical and economic parameters for design upscaling.

(iv) Encourage development of detailed designs for a large-scale power plant and IGCC technologies for implementation in the 5–10 year period.

(v) Encourage adoption of supercritical boilers.

On the R&D front, support must be considered for technology development covering pilot-scale studies on pressurized circulating bed combustion to obtain technical data on high ash Indian coals for design purposes, and for a facility for pressurized fluidized bed gasifier to study suitability of Indian coals for IGCC application. Design studies that need to be undertaken for large scale PFBC and for advanced IGCC technologies also deserve support. In the Indian context, further R&D work is needed in the areas of fly ash utilization, DENOX and HTHP particulate control technologies. BHEL had earlier worked on the development of slagging cyclone coal combustor technology. We need to pursue technology development efforts of this kind and bring them to the stage of practical applications instead of abandoning such efforts without proper evaluation. Basic research studies in gasification, combustion, and modelling must also receive attention.

It must, however, be recognized that basic and applied research, technology development and demonstration, and implementation of the best available technology must progress concurrently. In such an endeavour, it is essential to have active participation and mutual support among industries, academia, R&D labs and the Government in a well-focused and well-defined manner for finding optimal solutions to the dire energy situation that we face today.

Nuclear energy for power generation is gaining greater attention in many parts of the world in the context of climate change concerns as it offers significant potential for reduction of CO_2 emission. France derives 75% of its electricity from nuclear power. Japan and Korea are adding significant capacity. Opposition to nuclear power in countries, notably USA and Europe, has been strong due to various factors including safety considerations. For our country with a very low per capita energy resource endowment, all sources of energy including nuclear energy assume importance. Based on our modest uranium reserves of 70,000 tons and thorium reserves of 300,000 tons, the maximum capacity that can be built is about 10,000 MW of PHWR and with breeder technology it is about 300,000 MW. Apart from technical and economic considerations, public acceptance of nuclear power generation is essential for sustained effort in order to realize the share of nuclear power in our total energy mix projected at about 20,000 MW by 2020. In this effort, greater attention must be given to taking public into confidence of our capability with regard to nuclear safety, waste disposal, and decommissioning of nuclear power plants.

Considerable scope exists for introducing more efficient technologies in the transmission, distribution, and end use of electricity. Efforts are already underway in the country to introduce EHV and HVDC technologies in our electricity transmission systems. Continuation of R&D efforts to upgrade these technologies, to develop component technologies, and to ensure reliability should receive priority attention.

Improving the energy efficiency of end use devices is vital, as it tends to reduce the primary energy requirements. It must be stressed that the main purpose of conversion of primary energy to its final energy forms is to facilitate higher efficiency, convenience, and environmental compatibility of energy end use. End-use efficiency can be more important for the overall efficiency of the full fuel cycle than the upstream efficiencies themselves. End-use technologies are linked to particular forms of energy. For example motor vehicles and light bulbs are linked to different forms of energy, and often these technologies limit the flexibility for switching between different sources of primary energy and fuel forms.

In considering technology pathways, it is necessary to examine the combination of end-use technologies and associated fossil fuel cycles that could provide a full range of required energy services in the future with the highest overall efficiencies, economically and with minimal environmental impacts. For a variety of stationary end-use technologies, electricity is the final energy choice in combination with different fossil fuels. Motor fuels are the final forms of choice for combining (crude oil) with different mobile end-use technologies. This link between different fossil energy fuel cycles and characteristics of energy end use is what makes so important to improve performance of end use devices. Thus, demand side management (DSM) and other measures to improve the efficiency and reduce costs of energy end-use are as important as supply side improvements. In general, energy end use technologies require relatively modest investments in R&D.

Let me now turn to specific economic sectors of our economy. Technology aspects concerning energy consumption in agriculture and rural activities must receive much greater attention than before as there has been an accelerated growth of energy consumption in recent years reaching almost 30% of total energy. New and efficient technologies can have positive impact not only on energy consumption but also on increasing agricultural productivity. Potential energy savings can be found through changes in the use and design of irrigation pumps, tractors, post-harvest technologies (drying and storage technologies), improved silvicultural practices etc. Use of renewable energy technologies can also contribute to savings in fossil energy used in agriculture. Examples are solar and wind energy and energy from biomass residues or products from energy cropping for heat and power production, wind as direct source for irrigation and solar as direct source for drying. R&D activities must be directed to practical aspects of these opportunities.

Industry accounts for nearly 50% of total energy use. Within the industry, the largest energy users are the basic materials processing industries: steel, paper, cement, nonferrous metals, glass, chemicals etc. Major innovations are taking place elsewhere in the world focused on reducing the materials intensity in manufacturing processes and end-use equipment. The net effect of all these is a reduction of overall energy consumption and emission of pollutants and greenhouse gases. It must be recognized that many of the technologies used in basic materials production in the country today are relatively inefficient and outdated.

Many component technologies used in basic materials production can be made more efficient by proper choice of technologies. Much of the potential for improvement in technical energy efficiencies in industrial processes depends on how closely such processes have approached their thermodynamic limit. In industrial processes that require moderate temperatures and pressures, there is the prospect of introducing technologies for combined heat and power so as to achieve higher overall efficiencies. Fundamentally, new process schemes and substitution of materials, changes in design and manufacture of products resulting in less material use and increased recycling, can lead to substantial reduction in energy intensity. Take the case of electric motor drive system, which accounts for the largest share of electricity use in industry. Use of more efficient motors and variable speed drive systems can make a significant contribution to reduction of energy intensity of basic materials production in industry. Major effort will be needed to bring about process changes as these often yield even more substantial benefits than upgrading equipment piecemeal; and the benefits will go beyond energy alone.

Technology opportunities have expanded for improving the efficiency of end-use devices such as lighting systems, motors, domestic appliances, space conditioning systems etc. Our efforts must be intensified in introducing efficient technologies that are available with suitable adaptations as may be necessary.

Developments in emerging technologies must be closely tracked and necessary scientific capabilities must be built up. Let me mention by way of example certain new electrotechnologies that are being introduced that can impact strongly on efficiency of energy use. These span a wide range from microwave processing, electroseparation, and electrochemical synthesis in chemical industry to ultrasound processing, ozone disinfection, and radiofrequency drying technologies in textiles and carpet industries. Elsewhere, in pulp and paper industry use of membrane separation and biofiltration are being introduced. New energy technologies of interest in the food processing industries include ozonation and ultraviolet light for sterilization, electron beam processing and electronic pasteurization for meat and poultry. These have the potential to improve energy and environmental performance as well as industrial productivity.

Yet another technology pathway is the superconducting power equipment. Recent advances in high temperature superconducting (HTSC) materials – materials that can be cooled with liquid nitrogen. The long-standing promise of zero-resistance superconductors for utility applications is poised for practical realization in the next 10 years. Some applications of HTSC have already started to emerge. For example, the telecommunications industry is using chip-size HTSC signal filters in telephone repeater stations to reduce noise. For power industry, the new superconductor's projected benefits are indeed great. HTSC power cables will be capable of transmitting 3–5 times more current than comparable underground conduits. The new HTSC materials will also bring dramatic reductions in the size and weight of large motors, generators and power transformers.

In some advanced countries, several full-scale HTSC devices have already been, or are soon to be, tested on utility power systems. Superconducting motors of 200 HP have been built and operated; 1000 HP motors are next. Superconducting power cables that can carry 2000 A, 115 kV could be ready for commercial application in the early part of the next decade.

In our country as well, several research institutions have been engaged in HTSC research. Although the zeal with which a technology mission was started for HTSC is no longer visible; the importance of gaining ground on the scientific and technology aspects of HTSC remains undiminished. The effort that BHEL has been making in translating research results into practical applications in motors and generators deserves further support. Our scientists and technologists must reach out for strategic collaborations for introducing HTSC technology so as to take advantage of a technology of great potential that is still at an early stage of its application.

The rapid increase in the population of motor vehicles is a matter of concern not only because of their impact on demand for imported petroleum fuels but also because of serious problems of urban air pollution and public health in addition to greenhouse gas emission. In 1994, there were about 600 million motor vehicles on the road worldwide including commercial vehicles. At the present time, motor vehicles account for 15% of world CO_2 emission, and this share is increasing with increasing population of vehicles expected to reach about one billion by 2030. Given projected massive increases in motor vehicles from current level of about 5–6 million including two wheelers in our country, nothing less than a transcendental change will be required to protect our urban areas from dangerous levels of pollution.

Broad-based technological strategies will be required to address the challenges that lie ahead in transport sector. More efficient engine vehicle systems, alternate and cleaner fuels (CNG, ethanol, methanol, hydrogen), electric vehicle and fuel cell technologies, and better overall management of transportation sector demand and other measures will be needed.

In the short term, the technological pathway evidently is in the direction of increasing fuel efficiency through improved engine designs, electronic controls, continuously variable transmission as these are relatively easy to integrate into the current vehicle fleet. But in the medium and long term the solution lies in technological pathways that minimize emissions and ultimately to zero-emission vehicles powered by hydrogen.

Technology options based on ethanol and methanol as well as CNG must be pursued consistent with the availability of these fuels in different parts of the country. Alcohol blending is relatively simple and engine modifications required for this are minor, making its implementation easier. CNG is particularly well suited for use in trucks, buses and boats, provided filling stations can be set up rapidly. Safety aspects need special attention.

In the medium- and long-term electric vehicle (EV) technology can serve as one of the technology pathways for passenger cars, commercial vans, buses, and even motor cycles and scooters. All of the world's major automobile manufacturers are developing electric or hybrid electric vehicles for commercial production in the next decade. Toyota has already introduced a hybrid vehicle in the market. The major problem requiring attention is the storage battery that can give a range of 100–200 miles per charge with acceptable weight, service life and cost. A variety of battery and storage technologies are being investigated including batteries such as advanced lead acid, nickel hydride, sodium sulfur lithium ion, metal air and other devices such as fuel cells, ultracapacitors, flywheels, etc. The race is to apply leading edge technologies in advanced electric vehicles to reach performance, and price goals that can match conventional vehicles.

R&D for development of battery-powered vehicle technology in our country started as far back as 1974 with the involvement of CECRI, Karaikudi; BHEL, VRDE, Ahmedabad; and RDSO, Lucknow. Over a period of 5 years several prototypes were built and tested, notably by BHEL. Further development of battery powered vans by BHEL, and testing under actual user conditions in Delhi have yielded valuable information. Many technical challenges still remain, mainly concerning storage batteries. Some attempts by private sector to commercialize electric vehicles have not been successful. Our achievements in battery technology in terms of energy density and the number of charge-discharge cycles are still much below international results. Much remains to be done on vehicle technology to bring the application to the commercial stage.

There is a great deal of hope and expectation about fuel cell technology for automobiles. At present only the phosphoric acid fuel cell is being marketed commercially – largely for stationary combined heat and power markets in commercial and residential apartment buildings. Over 200 units in the range of 200 kW have been installed worldwide. Power densities achievable with this technology are low and as such are not suitable for cars.

The technology that is currently getting the most attention is the proton exchange membrane (PEM) fuel cell. This operates at a low temperature of around 80°C and offers both high power density (suitable for use in automobiles) and a prospective cost in mass production that might enable PEM cell electric vehicle to compete with internal combustion engine vehicle for automotive applications. Over the next 5 years, this technology is expected to be commercially available for transit bus, and building combined heat and power applications.

Most major automobile manufacturers abroad are developing fuel cell electric vehicles. Costs are currently high and many technology and engineering challenges still remain to be resolved. In the longer term, use of PEM fuel cells in automobiles will require a hydrogen production and delivery system. Until then, onboard fuel processors for use with either gasoline or methanol will be needed. For stationary applications, natural-gas-based fuel processors can be used. Progress in this area has been rapid. The proof-of-concept hydrogen-PEM fuel cell bus with compressed hydrogen storage was introduced by Ballard Power Systems only in 1993. By 1997, Ballard had sold and introduced several hydrogen-PEM fuel cell buses in Chicago and Vancouver. During 1998 Ballard and Daimler Benz, Toyota, Ford, GM and Chrysler have all announced plans to develop production-ready fuel cell cars by 2004.

Our efforts in this field in collaboration with BHU, IITs, and other institutions have been rather meager. Keeping these developments in mind, we must quickly expand our R&D capabilities in this field even if we perceive that benefits of this technology for our country can only be realized in the longer term.

Let me now turn to renewable energy technology pathways. Renewable sources of energy currently supply somewhere between 15 and 20% of the total world energy demand – mostly hydropower and biomass. There is growing realization that renewable energy technologies will play an increasing role in the future. The main challenge is to improve the cost-effectiveness of currently available technologies and to develop new ones. This is where increased thrust needs to be given to support well-defined R&D programmes with clear goals and practical orientation.

Recent major international studies indicate significant growth potential for renewable energy applications, particularly in scenario studies where environmental constraints are imposed. For example, the IEA study forecasts a 7.5 to 8.5 % growth in commercial use of energy from 'new renewables' by 2010. The WEC's ecologically-driven scenario forecasts a growth from 18% to 30% of the world's needs by 2020. The United Nations scenario forecasts a growth of up to 30% of world's needs met by renewables by 2025 and up to 45% by 2050.

To achieve substantial contribution from renewables to energy supplies at national and global levels would require:

- achieving rapid growth of renewable energy industry, thereby bringing with it significant employment opportunities;
- introducing market incentive to change the patterns of energy supply and use; and
- enhancing research, development, and demonstration to introduce innovations, reduce costs, improve performance, and establish market confidence.

India has built up an impressive record in the development and application of renewable sources of energy. Starting as a programme in the New Energy Division of the Department of Science and Technology in the mid-seventies, renewable energy development is now under the charge of a full-fledged ministry, supported by state-level agencies, a separate financial institution, research centers, university departments, and NGOs. A variety of industries – big and small are engaged in manufacturing activities covering a vast array of renewable energy systems from improved wood stoves and biogas plants to solar collectors and hot water systems, solar cells, modules and systems, biomass gasifiers, wind electric generators, small hydro systems etc. In addition, a variety of financing mechanisms have been introduced, and commercial banks are being associated with these financing mechanisms.

The overall strategy for the development and application of renewable energy involves support for R&D, demonstration projects and dissemination programmes through fiscal subsidies, incentives, and soft loans. All these actions have resulted in making India's renewable energy programme as one of the largest and wide ranging programmes in the world. The budgetary outlay stands at about Rs 400 crores per year. In terms of numbers of renewable energy devices or installations, the figures look impressive. Nearly a 1000 MW of wind power capacity has been established. A variety of solar thermal applications, such as water heaters and air heaters, have used more than 400,000 sq m of collectors. Over 150,000 solar PV systems aggregating 32 MW have been supplied. With an annual production of more than 11 MW of PV panels, India ranks among the top five countries in the world. Biomass and small hydropower capacities exceed 150 MW and 130 MW respectively. Biogas plants number about 2.5 million and improved wood stoves 25 million.

Despite all these achievements the overall impact on the energy sector is still relatively small. The time has come to refocus renewable energy development and redirect science and technology inputs in ways that can provide a new thrust and help in mainstreaming renewable energy into the overall energy sector activities. It is quite conceivable that renewable energy can contribute a respectable share of 10% of grid power by 2012 and about 29% by 2020. For this to become a reality, a whole range of actions will have to be taken with strong leadership provided from both policy and technical levels.

As I said before, there is widespread recognition that the country has made significant strides in the development and utilization of renewable sources of energy. We have a long way to go before renewable energy starts impacting on the energy scene in any significant manner. Our renewable energy R&D capabilities remain rather fragmented. We should bring greater coherence to our national programmes and more focus on our efforts. We should also establish greater cohesiveness among the academia, R&D labs, industry and business. Let me now outline some key areas where we need a major thrust.

Our strengths in solar technologies, both thermal and photovoltaics, must now be harnessed to increase substantially the industrial and commercialization activities. We must vigorously explore the solar thermal options (parabolic trough, dish and power tower) for grid power applications. In this connection, the proposals for solar power plants in Rajasthan and other states must receive serious and expeditious consideration. Other solar thermal technologies such as solar-assisted heat pumps, solar cooling and drying and dehumidification technologies must be brought out of the lab into the stage of practical applications.

We are among the top five countries in the world in solar photovoltaics. We have established capabilities in the production of silicon material, solar cells, modules and a variety of systems. Both crystalline and thin-film technologies are witnessing tremendous improvements in efficiency and reduction of costs. International prices of PV modules have reached $4 per peak watt. Further reductions are anticipated in the next 5 years. We must participate even more vigorously in the international effort to achieve a breakthrough in this revolutionary technology.

We need to modernize our crystalline silicon PV industry for which we need to increase our support for R&D. We need to enhance our capabilities in thin-film PV technologies, both amorphous and polycrystalline thin-film technologies. Past efforts in building momentum for developing amorphous silicon thin-film technology went as far as establishing a pilot plant. This momentum seems to have been lost in the last couple of years. We must reinforce earlier efforts and help in upgrading the pilot plant to enable it to develop multijunction thin-film technology. Plans must be laid out to establish commercial production of thin-film PV with the participation of public and private sectors.

One of the key actions that the Ministry of Nonconventional Energy Sources has recently taken is establishing a national institute called the SSS National Institute of Renewable Energy to draw together our country's national research, development and demonstration efforts within one organization and direct the national efforts in a focussed manner. To the best of my knowledge, the institute will not engage itself in all R&D activities but will coordinate and support the various R&D centres in academia, national R&D labs, demonstration centres, and industry. The priority areas for this Institute to address are: upgrading the amorphous silicon plant; strengthening the solar energy centre at Gwal Pahari to serve as a national center for testing, standardization, training and market demonstrations with its own regional test centres; facilitating the development of wind energy test and certification facility; updating wind data/map; coordination of the work of biomass centres and industrial activity in bio fuels; development of coordinated programmes in areas of energy storage including hydrogen, fuel. cells, battery systems, power conditioning systems; software development; alternate fuels and vehicle systems; promotion of development of hybrid energy systems; economic and policy analysis; and education and training.

In conclusion, let me say that energy is critically important as it has a pervasive role in modern life. Securing energy for sustainable development is not only challenging but is also full of opportunities. The challenges and tasks that lie ahead in modernizing our energy industry, introducing new and more efficient technologies, and infusing necessary dynamism in the energy sector as a whole, can be managed in an effective manner provided that our scientists, engineers, technologists, managers, planners, entrepreneurs, and administrators all work in concert with dedication, commitment and common purpose.

Public policy measures such as taxes and incentives, market forces, and new technologies influence the way energy use will evolve in the country. These factors are in a way interdependent. Both markets and technology can be affected by policy. The three factors must be used to accomplish energy sector objectives namely, providing secure energy supply at reasonable price in an environmentally acceptable manner.

The arguments for a coherent national energy R&D policy are derived from the linkages among energy and economic, environmental and national security considerations on the one hand, and from the potentially serious inadequacies of the current mix of fuels and energy options, on the other.

It is gratifying to note that TIFAC in its Technology Vision 2020 on power sector has addressed some of the challenges and has set up an action team for developing a few mission-oriented proposals in the energy sector. Debates on the energy sector will continue in various forums in the country. A principal lacuna that exists in articulating the agenda for energy R&D, after a critical examination of merits and limitations of various options, is the absence of a standing group of energy R&D professionals in the country. If initiatives are forthcoming to establish such a group, the composition of such a group should consist of representatives of all key actors in the energy sector and must share a common understanding of technological pathways and bring objectivity into evaluating options for making rational choices. Advocates of each class of energy options (for example, nuclear fission, fossil fuels, renewables, and end-use efficiency) tend to disparage the prospects of the other class of options; these tendencies are exacerbated by the zero sum characteristics of energy R&D funding. In this way, the energy community itself comes up with divergent arguments such as – 'renewables are too costly', 'fossil fuels are dirty', 'nuclear fission is too unforgiving', 'fusion will never work', 'efficiency means belt tightening and sacrifice or is too much work for consumers' – that the budget cutters cheerfully employ to cut energy R&D budget one at a time and render it subcritical.

While this scenario may sound all too familiar to most of us, it is time that we reachout beyond narrow considerations and accept the niche for each source of energy. We need all sources of energy and no single source will displace all others. Support for R&D must reach out for a reasonable balance among the different technology options. I wish that DST publishes comparative data and analysis on energy R&D budget for the last twenty years for each category namely, fossil, renewables, fission, fusion, conservation, Bio/environment and basic energy sciences. This will reveal the wide budget disparities among the different categories and hopefully prompt a more rational allocation of R&D for them during the next two decades.

REVIEW ARTICLE

Role of abscisic acid in plant stress tolerance

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The phytohormone abscisic acid (ABA) plays a regulatory role in many physiological processes in plants. Different stress conditions such as water, drought, cold, light, and temperature result in increased amounts of ABA. The action of ABA involves modification of gene expression and analysis of responsive promoters revealed several potential *cis*- and *trans*-acting regulatory elements. The nature of ABA receptors is unknown. The precise role of ABA under both abiotic and biotic stress conditions, while unclear, is of current interest in many laboratories in the world. Molecular mechanisms underlying the role of ABA in stress tolerance in plants need to be understood.

UNDERSTANDING responses of plants to their environment in terms of adaptability and performance is of paramount importance. Apart from interest in factors important for ecological and evolutionary distribution, much present day interest is fueled by practical needs. Modern agriculture is affected by environmental factors such as water, drought, temperature, light, and salt stress. Sustainable agriculture in harsh environments requires an understanding of the ways that plant genes respond to both biotic and abiotic factors. Interest in low impact sustainable agriculture (LISA) has increased considerably, reflected by the burst of activity in genetic engineering.

Stress may induce common responses such as enhancement of plant hormones. For instance, wounding can induce the production of increased ethylene, auxin, and abscisic acid (ABA). Since many kinds of stresses including water, salt, and cold temperatures, induce ABA synthesis, ABA may be considered a plant stress hormone. It regulates several important aspects of plant growth and development. Recent studies have demonstrated a pivotal role for ABA in modulation at the gene level of adaptative responses for plants in adverse environmental conditions[1-6]. ABA is also involved in several other physiological processes such as stomatal closure, embryo morphogenesis, development of seeds, and synthesis of storage proteins and lipids[7-11], germination[12-17], leaf senescence[18], and defense against pathogens[19,20]. Nevertheless, ABA acts as a mediator in controlling adaptative plant responses to environmental stresses[21-23]. In several instances, it has been implicated in signal transduction at the single-cell level[24].

Abscisic acid biosynthesis

In 1960, ABA was isolated and identified from cotton bolls[25]. Mutants of ABA biosynthesis are known from a variety of plant species[26,27]. Characterization of these mutants together with their physicochemical studies has enabled the pathway of biosynthesis to be elucidated in higher plants. However, questions still remain. There is evidence that either of two different routes may be used (Figure 1). In both the cases, ABA is synthesized via the mevalonate pathway, as are all terpenoids. The hormone may be synthesized directly through the mevalonic acid pathway via the 15-carbon precursor, farnesylpyrophosphate. Alternatively, it may be formed indirectly by the cleavage of the 40-carbon carotenoid precursor, violaxanthin, also synthesized via the mevalonate pathway. Both pathways may be used for the synthesis of ABA, but in different tissues or different conditions[18,19,27,28,30,31]. Two genes involved in ABA biosynthesis have been cloned, and should provide insight into the regulation and site of ABA synthesis[29,32]. It is believed that the hormone is synthesized in mature leaves and transported in the phloem through the shoot system.

Increased ABA levels as a response to environmental stress

During vegetative growth, roots of many angiosperms synthesize ABA and transport it into the shoots under conditions of water stress. ABA is an essential mediator in triggering plant responses to adverse environmental stimuli[18,33,39]. This is known to occur in a number of crop plants which include rice[35], barley[36], soybean[37], tomato[38], cotton[39], and alfalfa[40]. Leaf ABA content in wild plants increased with water stress. Upon rehydration, the ABA level ceased to increase and returned to pre-stressed levels[34,36-38]. Substantial evidence suggests that increased ABA levels limit water loss by reducing stomatal aperture.

Chilling temperatures also increased ABA levels[21]. In crops such as winter wheat, potatoes, and alfalfa, a large

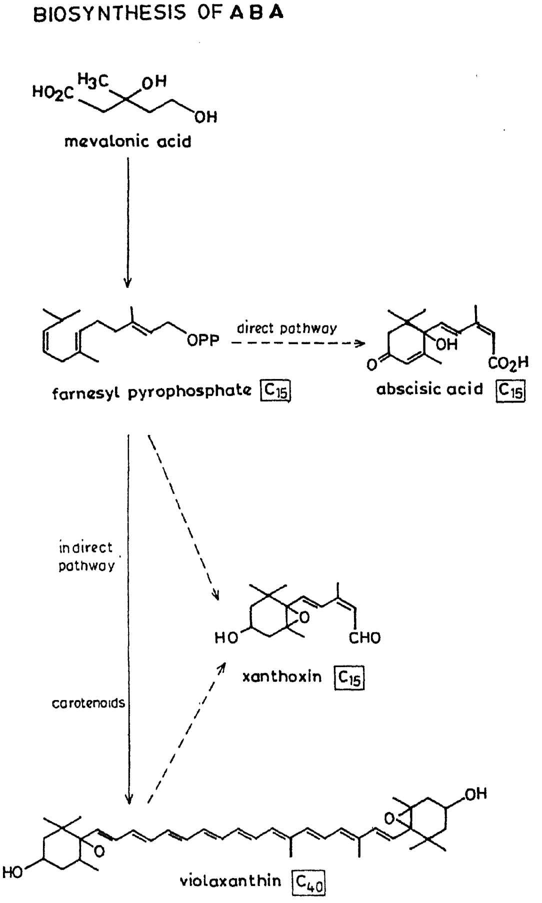

Figure 1. Schematic representation of biosynthetic pathways of abscisic acid. The hormone may be synthesized directly through the mevalonic acid pathway via the 15-carbon precursor, farnesylpyrophosphate. Alternatively, it may be formed indirectly by the cleavage of the 40-carbon carotenoid precursor, violaxanthin, also synthesized via the mevalonate pathway.

increase in the ABA content of leaves was observed during hardening and cold acclimation[1,40–42]. However the extent of the ABA response depends on varietal differences – particularly in winter wheat[41]. A freeze-resistant variety of wheat had a higher ABA level than a less resistant variety, although the difference was not significant[42]. Similarly for potato species, an increase in ABA was observed in *Solanum commersonii*, but not in *S. tuberosum*, which failed to acclimate at –3°C.

Salt stress resulted in intercellular accumulation of ABA during growth of tobacco cells[4] and elevated endogenous levels of ABA in seedlings of alfalfa[40]. Mechanical injury to potato leaves resulted in an increase in ABA levels[6], and increased ABA expression of transcripts coding for protease inhibitor. Similar treatment of an ABA-deficient mutant had little effect. Young tobacco leaves had elevated levels of ABA following infection by tobacco mosaic virus (TMV).

From the above observations, it is evident that the extent of ABA production is positively related to the degree of resistance to a given stress factor. However these observations alone do not establish that ABA is a necessary intermediary for acquisition of stress tolerance.

Exogenous application of ABA and stress tolerance

Exogenous application of ABA was able to increase plant adaptive response to various environmental conditions. The resurrection plant, *Craterostigma plantaginem* can tolerate extreme dehydration. However, *in vitro* propagated callus derived from this plant has a strict requirement for exogenously applied ABA in order to survive severe dehydration. Therefore, addition of ABA (5 mg/l) to the callus of *Craterostigma plantaginem* (resurrection plant) induced tolerance to dessication[43].

Abscisic acid, when added to suspension cultures of tobacco (*Nicotiana tabacum* L. cv. Wisconsin) induced adaptation to salt stress[44,45]. The role of ABA in wound-induced expression of the proteinase inhibitor II gene is well demonstrated[6,46]. These plants have been shown to accumulate inhibitors when the leaves are wounded. These inhibitors appear to play a significant role in preventing damage by insects. In addition, several studies have convincingly demonstrated that exogenously applied ABA can indeed increase cold tolerance. Application of ABA at room temperature increased cold resistance in callus explants of tobacco[47], cucumber, winter wheat[48], and alfalfa[49]. However, in some cases, exogenous application of ABA did not increase stress tolerance[50]. The failure may be attributed to lack of ABA uptake or its degradation by microbes. Sterile suspension cultures overcame these problems[2,44,51–53] Cell suspension cultures of winter wheat, winter rye, and Bermuda grass, on being treated with ABA, could tolerate extremely cold temperatures (–30 to –60°C).

Most reports have demonstrated that the application of exogenous ABA provides tolerance to various stress conditions. However, endogenously produced ABA may not show the same effects as elicited by exogenously applied hormones; and, of course, correlated variations may not reflect the cause.

ABA-deficient and ABA-insensitive mutants

Mutants are powerful tools for investigating the role of ABA in stress tolerance[22]. Mutants have been obtained for *Arabidopsis*, tomato, and potato that have been either unable to respond to the hormone or have been unable to synthesize ABA. The two different types of ABA regulatory mechanisms in these plants[54–56] are *aba* (ABA deficient) mutations which affect synthesis of ABA (ref. 56), resulting in lower ABA levels; and *abi* (ABA-insensitive) mutations which impair ABA sensitivity. Three ABA-insensitive mutants of *Arabidopsis*; *abi1*, *abi2*, and *abi3* have been found. The product of the *abi3* gene acts primarily in seed development[13]. The role of ABA in signaling stress has been extensively documented by molecular studies showing that ABA-deficient mutants are affected in the regulation of many genes by drought, salt, and cold[22,26,57]. ABA has also been shown to be involved in the induction of gene expression by mechanical damage[58].

ABA induces closure of stomata. Water stress in the roots can lead to a 40-fold increase in the ABA levels in the plant. An ABA-deficient tomato mutant, *flacca*, is unable to close stomata during drought stress[59–61]. The *flacca* mutant had only 20–26% of the ABA content of wild-type tomatoes when well-watered. Water stress did not result in additional amounts of ABA (ref. 61). Moreover, the wilted character of the *flacca* mutant could be phenotypically reversed with ABA application[62]. Comparative analysis of proteins from wild-type and *flacca* mutants with 2-dimensional electrophoresis indicated that several polypeptides are specifically synthesized during adaptation to drought stress[38,63,64]. Synthesis of new polypeptides occurred when ABA was applied to the *flacca* mutant, indicating regulation by ABA concentrations during drought stress.

The relationship between ABA and cold tolerance has been well documented. While no apparent effect on tolerance to freezing was observed in *abi* mutant, cold tolerance was markedly impaired in the *aba* mutant compared with wild-type[65]. This observation supports the idea that the level of ABA during cold acclimation appears to be important for the development of tolerance to freezing. Expression of ABA-regulated *cor* (cold regulated) genes was unaffected by *abi2* and *abi3* mutants, but was greatly reduced in the *abi1* mutant. Cold-regulated expression of all three *cor* genes was unaffected in *abi1* mutant plants. Thus it is concluded that cold-regulated and ABA-regulated expression of the three *cor* genes may be mediated through independent mechanisms. Similar observations were made in alfalfa[49,66]. Likewise, the role of ABA in the wound-induced expression of proteinase inhibitors I and II has been well documented using ABA-deficient potato and tomato mutants[6]. Proteinase inhibitors I and II are regulated by PI and PII genes. Local wounding of potato and tomato plants resulted in accumulation of proteinase inhibitors PI-I and PI-II in the aerial parts of the plants[67]. On the other hand, ABA-deficient mutants of potato (*droopy*) and tomato (*sitiens*) showed considerable reduction in expression of these genes in response to plant wounding when compared to wild-type plants. External application of ABA completely abolished the proteinase inhibitor II (PI-II) induction of wild-type and mutant plants.

Stress and ABA-inducible proteins

Plants synthesize a spectrum of new proteins on exposure to different environmental stresses such as water stress[38,43,63,64,68–72], salt stress[3,73–78], dehydration and desiccation stress[79–81], cold stress[5,49,53,56,82–89], and wounding[6,40]. Proteins induced by stress fall into three categories: (i) those inducible by stress and ABA; (ii) specifically induced by stress but not by ABA; and (iii) inducible by ABA. Therefore, it is quite evident that many of these stress-responsive proteins are also induced by ABA (Table 1) and several groups of proteins listed are homologous.

Late embryogenesis abundant proteins

Genes encoding late embryogenesis abundant (LEA) proteins were consistantly represented in differential screens for transcripts with increased levels during drought. These proteins were first described in research on genes abundantly expressed during the final desiccation stage of seed development. Circumstantial evidence for their involvement in dehydration tolerance is strong. The genes are similar to many of those expressed in vegetative tissues of drought-stressed plants (Table 2). ABA can also induce *lea* genes in seeds and vegetative tissue[8,22]. The LEA proteins are divided into six groups based on deduced amino acid sequence homologies and dot matrix analysis with proteins from cotton. These groups were D19-LEA (group 1), D11-LEA (group 2 – also called dehydrins), D7-LEA (group 3), D113-LEA (group 4), D95-LEA (group 5), and D29-LEA (group 6 – may be similar to group 3). This system will remain useful until clear functions can be assigned to each gene. Each group has a stretch of amino acid sequences which is highly conserved among the proteins belonging to that group. These proteins are extremely, hydrophilic, remain heat stable at high temperatures, are basic and contain no cysteine and tryptophan. Two exceptions are the proteins from *Creterostigma plantagineum* and D11-LEA from cotton plants. Proteins of this group, including most of the *rab* genes[90], and some of the dehydrins and *lea* genes are also inducible by environmental stresses like salinity[91,92].

Another family of genes induced by multiple stresses and ABA-encoded proteins are rich in glycine (35–40%) (ref. 40). They also contain histidine, asparagine, and tyrosine in lesser quantities than glycine. All encoded proteins contained tandom repeats comprising glycine residues interrupted with histidine or tyrosine. Interest-

Table 1. Stress-responsive and ABA-inducible proteins

Crop	Clone name	Nature of stress	Organ specificity	Reference
Rice	RAB 16 A, 16 B,	Salt and desiccation	No	74
	16 C, 16 D	Salt and desiccation	No	106
	–	Salt and desiccation	Shoot and root	75
	GRP	Water	Doubtful	14
Wheat	EM	Drought	No	105
	RAB 15	Drought	No	72
Barley	dehydrins B8, B9, B17 and B18	Desiccation	No	80
	PH VAI	Cold	Doubtful	39, 89, 128
	GRP	Not known	Doubtful	126
Maize	pMAH9	Drought and wounding	No	69
	dehydrin M3	Desiccation	No	80
	RAB-17	Not known	No	136
	HS 70	Heat, desiccation and wounding	No	68
Cotton	LEA D7, D11, D19, D29 and D34	Not known	No	79
Tobacco	Osmotin	Salt	No	73, 128
Tomato	TAS 14	Salt and drought	Not known	76
	PLE 4	Salt; drought; cold; heat	Shoot and seed	64
	PLE 16	Salt; drought; cold; heat	Shoot and seed	71
	PI-II	Wounding	Leaves	6
Potato	PI-II	Wounding	Leaves	6

The data is adapted from compilations of Ma Luo *et al.* 1993.

Table 2. Genes encoding late embryogenesis abundant (LEA) proteins during drought stress

Plant name	cDNA[a]	Relationship of encoded polypeptide type	Reference
Helianthus annus (sunflower)	Hads10	D19-LEA	129
Triticum aestivum (wheat)	Em	D19-LEA	130
Hordeum vulgare (barley)	B19.1; B19.3; B19.4	D19-LEA	131
Lycopersicum esculentum (tomato)	PLE25	D113-LEA	132
Helianthus annus	Hads11	D113-LEA	129
Arabidopsis thaliana	pRABAT1	D11-LEA	133
Craterostigma plantageneum (resurrection plant)	pc C27-04	D11-LEA	70
Zea mays (maize)	M3 (RAB-17)	D11-LEA	80
Hordeum vulgare	B8; B9; B17	D11-LEA	80
Lycopersicum esculentum	PLE4	D11-LEA	132
L. esculentum	TAS14	D11-LEA	70
L. chilense	PLC 30–15	D11-LEA	76
L. plantageneum	pcC 6–19	D11-LEA	134
Stellaria longipes	H26	D11-LEA	135
Orzya sativa (rice)	pRAB16	D11-LEA	120
Daucus carota	pcECP40	D11-LEA	136
A. thaliana	ERD10; ERD14	D11-LEA	136
T. aestivum	pMA2005	D7-LEA	80
T. aestivum	pMA1949	D7-LEA	80
C. plantageneum	pcC3-06	D7-LEA	90
C. plantageneum	pcC27–45	D95-LEA	90

[a] The best characterized plant genes from which cDNA clones have been demonstrated to show increased mRNA expression in response to drought stress and also absisic acid.

ingly, these proteins showed striking homologies with other ABA-responsive proteins[40,69]. Therefore, it is quite clear that a wide spectrum of proteins are synthesized by the induction of ABA or environmental stresses (Tables 1 and 2). Most of the proteins are cloned to clarify their identities, but their function in stress tolerance is yet to be elucidated.

Regulation of stress and ABA-inducible gene expression

Drought and low temperatures are adverse environmental conditions that affect plant growth and crop productivity. Plants may have similar mechanisms to tolerate both. For example, ABA is produced under both drought and low temperature stress. Also, plants grown under water stress show a higher tolerance to low temperature stress than do well-watered plants.

A number of genes have been described that respond to drought and low temperature stress at the transcription level. The functions of some gene products have been predicted from sequence homology with known proteins and are thought to play a role in protecting cells from water deficits and low temperatures[57,93,94].

Most of the drought and cold-stress-inducible genes that have been studied to date are also induced by ABA. Dehydration appears to trigger the production of ABA which in turn expresses various genes. *Cis-* and *trans-*factors involved in ABA-induced gene expression have been analysed extensively[22,26,95,96].

Several genes in *Arabidopsis* are induced by both cold and drought in ABA-deficient (*aba*) and ABA-insensitive (*abi*) mutants. This suggests that these plants under conditions of cold and drought do not require ABA but do respond to it[51,93]. The genes include *rd29A/ilti78*, *kin1*, *cor6.6/kin*, and *cor47/rd17* (refs 30, 97–100). The promoter region of the *rd29A* gene was analysed, and a novel *cis*-acting element responsible for dehydration and cold-induced expression was identified at the nucleotide sequence level, using transgenic plants. A 9-bp conserved sequence, TACGACAT, termed dehydration responsive element (DRE), is essential for regulation of dehydration-responsive gene expression. The DRE has been demonstrated to function as a *cis*-acting element involved in the induction of *rd29A* expression by low temperature stress[30].

DRE-related motifs have been reported in promoter regions of cold- and drought-inducible genes such as *kin1* and *cor6.6*, and *rab17* (refs 100, 101). A similar motif was also reported (C-repeat TGGCCGAC) in the promoter region of the cold-inducible rape oil-seed gene *BN115* and in a low temperature-responsive element[102]. These results suggest that DRE-related motifs are involved in drought- and cold-responsive but ABA-independent gene expression. Recently, two independent families of DREB proteins, DREB1 and DREB2, have been reported to function as *trans*-acting factors in two separate signal transaction pathways under low temperature and dehydration[103,104].

Many of the changes in mRNA levels observed during various types of stresses reflect a transcriptional activation. Exogenous application of ABA can also induce these changes and this treatment has been utilized for setting up experimental systems to define *cis-* and *trans-*acting elements. To obtain a clear understanding of the transcriptional control mechanisms of ABA and stress induction by identifying *cis*-acting regulatory sequences, the corresponding genomic clones of some ABA- and stress-inducible proteins have been isolated and their nucleotide sequences analysed[71,74,77,105,112].

A functional analysis of the S′ upstream sequences for the *Em* gene of wheat identified a 50-bp ABA-responsive element (ABRE) that was capable of conferring ABA-inducibility in either orientation in a minimal cauliflower mosaic virus (CAMV) promoter[91,105]. Two elements, *Em1* and *Em2*, within this 50-bp ABRE were in the promoter of the other ABA-responsive genes, such as the *ita* and *rab* gene family[74,77,106,107]. A DNA-binding protein (EM bp-1) that interacted specifically with an 8-bp sequence in the *Em1* element (ACGT) with the mutation (CCCGGGGC) in the core (ACGT) of this sequence (CACGTGGC) prevented binding of EM bp-1 and reduced the ability of ABRE to confer ABA responsiveness to a CAMV promoter. These findings clearly suggest that the sequence CACGTGGC in one of the responsive elements and the DNA-binding protein EM bp-1 are involved in ABA response.

In contrast, ABRE motifs are not involved in ABA regulation of other stress-inducible genes such as in the *Arabidopsis thaliana* Rd (ref. 108) and the *Craterostigma plantagineum* CdeT27-45 genes[109]. The distinct sequence motif is essential for the ABA response to CdeT27-45. In this case the corresponding physiological *trans*-acting factors are presumably unknown. Genes that are induced by ABA and encode other potential transcription factors, include the box gene *ATHB-7* and several *myb* homologues from *A. thaliana*[110] and *C. plantagineum*[111]. Comparison of the available promoter sequences of ABA and stress-inducible genes revealed that ACGT cores were conserved in many promoter elements of these genes[112–114]. The existence of the ACGT core sequence in the promoter region of these genes suggests that the genes may be mediated by ABA (refs 115, 116). Previous work has shown that a 50-bp ABA responsive element (ABRE) is capable of conferring ABA inducibility. Cauliflower mosaic virus (CAMV) promoter and the sequence CACGTGGC is included in the 50-bp ABRE element containing a TGCA core[117,118]. It should be noted that promoter regions of many ABA-responsive genes contain more than one sequence element with an ACGT core. Whether these are involved in the ABA or stress response remains to be tested[105,107,119,120].

The best characterized *cis*-element in the context of drought stress is the ABA-responsive element (ABRE) which contains the palindromic motif CACGTC with the G-box ACGT core element[113]. ACGT elements have been observed in many plant genes regulated by diverse environmental and physiological factors. Systematic binding studies have shown that nucleotides flanking the ACGT core specify the DNA–protein interactions and subsequent gene interaction[100]. G-box-related ABREs have been observed in ABA-responsive genes, although their functions have not been proven experimentally. However, for several of these genes, the G-box type of ABREs, already described for ABA induction, both in seeds and in vegetative tissues have been found[107,116,118,119].

Most research has focused on understanding how relevant genes are up-regulated during different types of environmental stresses. However, the abiotic stress factors also involve down-regulation of several genes. For example, studies of *C. plantagineum* have shown that transcripts encoding proteins relevant to photosynthesis are down-regulated during dehydration and thus reduce photoxidative stress. It has been shown that promoter regions of storage protein genes contain information for their down-regulation during seed desiccation[90,121]. The role of cold-responsive genes in freeze tolerance has been discussed recently[122].

There is a viviparous mutant (*vpl*) of maize in which the embryos do not become dormant[107]. This mutation reduces the sensitivity of the embryos to ABA without affecting ABA synthesis. The wild-type *vpl* gene product probably is involved in either the receptor mechanism for ABA or the signal transduction pathway. The *vpl* mutation also has pleiotropic effects on anthocyanin synthesis during seed development. In the wild-type, anthocyanin pigments are synthesized and accumulate in the aleurone layer of seed, but in the *vpl* mutant, this synthesis is blocked because the gene product is required for the expression of the *cl* gene. The *cl* gene encodes a transcriptional factor that regulates the genes encoding enzymes required for anthocyanin synthesis[9,123,124]. The *vpl* gene has been cloned, the transposor tagged, and sequenced. The *vpl* gene most likely produces a transcription factor involved in regulation of the expression of other genes. The *vpl* protein appears to activate the transcription of the *Em* gene which is promoted by ABA, but direct binding of *vpl* protein to regulatory elements in promoters of the *Em* or the *ccl* gene has not yet been observed. The *vpl*/AB13 proteins thus appear to be multifunctional transcription factors that integrate ABA and other regulatory signals in seed maturation, most likely by interacting with distinct *trans*-acting factors that remain to be identified[125]. It is quite evident from the above studies that environmental stresses induce an increase in the ABA content of plants in a species-dependent manner.

Conclusions and perspectives

Environmental stresses like cold, drought, desiccation, salt, and mechanical wounding induce the synthesis of ABA. Despite genetic differences, exogenous application of ABA accelerates the rate of plant acclimation to given stress conditions, while studies with ABA-insensitive and ABA-deficient mutants clearly reveal that ABA plays a cardinal role in plant adaptation to stresses. At the molecular genetic level, ABA-responsive genes have been identified and their expression studied. However, the precise role of ABA in stress tolerance has not been pinpointed. ABA regulates the process of adaptation into two interacting steps. First, ABA acts via differential signal transduction pathways on cells which are the least and most affected by the imposed stress. Second, ABA may regulate through some genes/gene products, which control the expression of stress or adaptative-specific genes. Some genes are up-regulated and others are down-regulated, resulting in overall synthesis of genomic products which may play a role in plant survival under diffferent environmental conditions. Despite the rapid progress in analysis of several ABA-responsive genes, key questions remain to be answered. For instance, does ABA interact with these genes directly? Do ABA and stress-specific genes coordinate regulation by *cis/trans*-acting factors? What are the functions of the ABA-responsive genes? Current research carried out in various laboratories worldwide is expected to provide answers to the above questions and also unravel the molecular mechanism(s) underlying stress tolerance in plants.

The level of understanding at the molecular level of stress-induced ABA synthesis has increased greatly in recent years. With a bit more knowledge, it might be possible to control levels of ABA and consequently plant-response to stress. Certainly exciting times lie ahead in this rapidly-changing field.

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Somatic embryogenesis and plant regeneration from male flower buds in banana

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Embryogenic cultures were established using young male flowers in five cultivars of banana (*Musa* spp.). Embryogenic callus continued to rapidly proliferate on MS medium supplemented with 0.22 μM BA and 1.14 μM indole-3-acetic acid (IAA) and somatic embryos developed during subcultures on the same medium. Green plumule emerged from the embryos followed by the development of roots within a span of 6 to 8 weeks upon transfer to ½ strength Murashige and Skoog medium (MS) + 0.5 g/l malt extract (ME) and 0.1% activated charcoal (AC) and subsequently developed into complete plantlets. Normal plant development was noticed following transplantation into paper cups in the greenhouse.

BANANAS and plantains are one of the world's major fruit crops and staple food for millions of people. In India, banana ranks fourth in terms of gross value after paddy, wheat and milk and is the largest fruit crop, in terms of production. Majority of the edible bananas are triploid and are propagated vegetatively by suckers. In addition to this, sterility and polyploidy often hamper the breeding programmes for the development of superior banana varieties.

Plant cell and tissue culture techniques have helped in the rapid multiplication of elite varieties employing shoot tips or floral apices[1]. Somatic embryogenesis has been reported from leaf sheath or rhizome fragments from *in vitro* plants[2], thin sections from proliferating buds[3], immature zygotic embryos[4] and male flower bud cultures[5,6]. Somatic embryogenesis leading to embryo production and plant regeneration offers advantages for mass propagation of elite cultivars and also provides a useful system for genetic manipulation[7,8]. In the present communication, we report on the initiation and maintenance of highly proliferating embryogenic callus and plant regeneration in some elite Indian banana cultivars.

Materials and methods

Experimental plant material included cvs. Rasthali (AAB), Basrai (AAA), Shreemanti (AAA), Lokhandi (AAA ?) and Trikoni (AAA ?). Male inflorescences collected from the field-grown plants, were surface cleaned with absolute alcohol. Under a sterile laminar air flow, the outer enveloping bracts were removed and the inner part (2–3 cm in length) containing male flower primordia (from 0 to 15, 0 being the meristem) was isolated. Individual male flower primordia were cultured on Murashige and Skoog[9] medium (MS) or White's[10] medium supplemented with 18.10 μM 2,4-dichlorophenoxy acetic acid (2,4-D), 5.37 μM napthalene acetic acid (NAA), 5.71 μM indole 3-acetic acid (IAA) and 4.09 μM *d*-biotin, 3% sucrose and 0.2% gelrite for callus induction. For the proliferation of callus and somatic embryo induction, a medium supplemented with 0.22 μM benzylaminopurine (BA) and 1.14 μM IAA, 3% sucrose and vitamins[11] was used. Callus was also cultured on media supplemented with mannitol (3%), to study its effect on embryogenic callus development. The pH of all the media was adjusted to 5.7 prior to autoclaving and all the cultures were maintained in an incubation room at 25 ± 2°C and 12 h photo-period with 1000 lux.

For conversion of somatic embryos into plantlets, ½ strength MS medium supplemented with 0.5 g/l malt extract (ME) and 0.1% activated charcoal (AC), Morel's vitamins, 3% sucrose and 0.2% gelrite were employed. Fully grown plantlets with good shoot and root system were then transplanted into paper cups with soilrite and then into polybags in the greenhouse.

Results and discussion

Male flower buds cultured on MS or White's medium supplemented with 18.10 μM 2,4-D, 5.37 μM NAA, 5.71 μM IAA and 4.09 μM *d*-biotin, showed enlargement of the floral primordia and the development of whitish embryogenic callus, after 2 to 3 months of inoculation (Figure 1 *a*). MS medium was found to be better than the White's medium (41.6%) for embryogenic callus (66.5%). The embryogenic callus showed several developed embryos on the surface and the smear preparations of the callus tissue showed early stages of embryo development (Figure 1 *b*). The embryogenic tissues showed repeated proliferation during subcultures on MS + 0.22 μM BA + 1.14 μM IAA, resulting in an increase by 8.07-fold callus fresh weight for each

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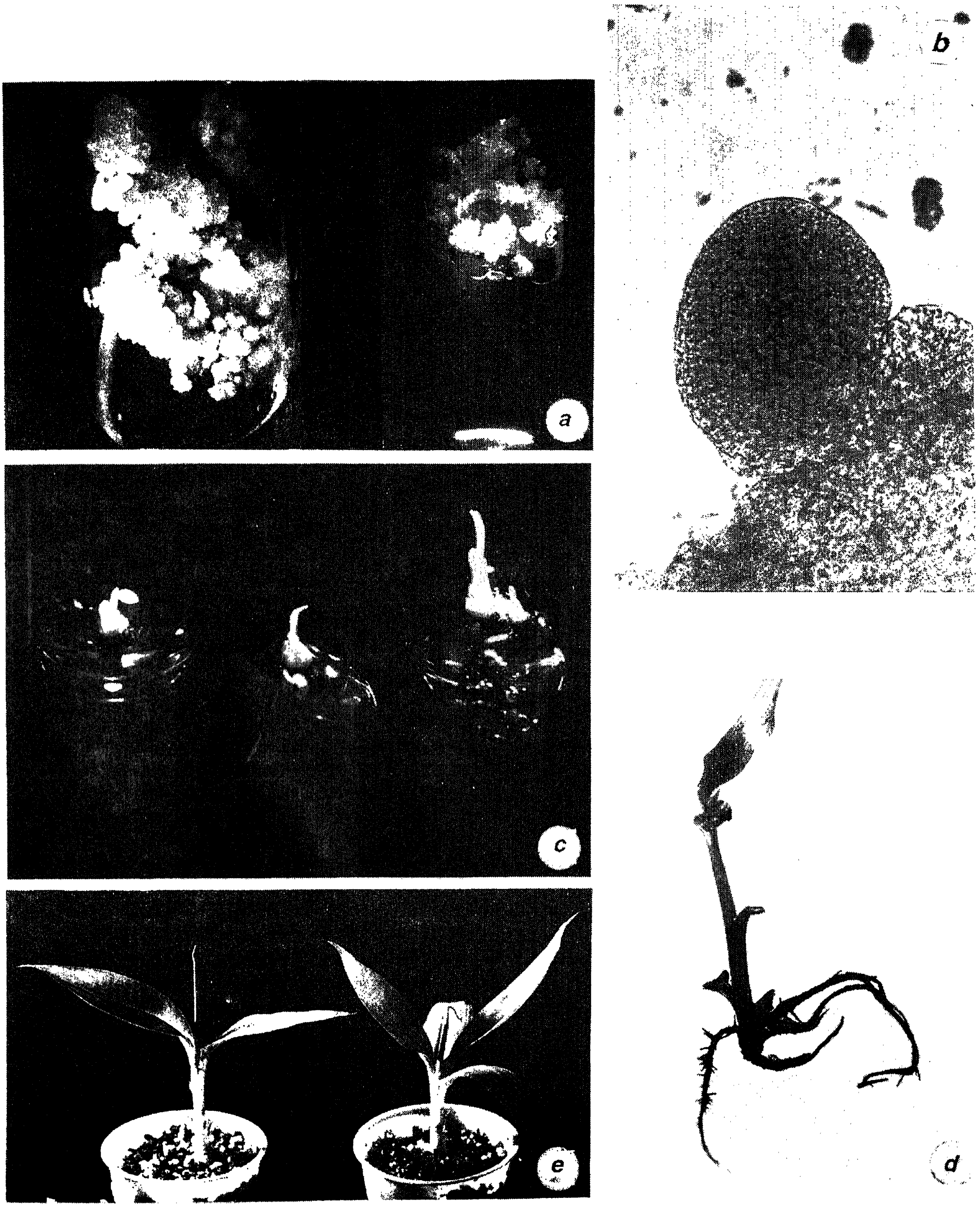


Figure 1 ***a–e*****.** Somatic embryogenesis and plant regeneration from male flower buds of banana cv. Rasthali. ***a***, Embryogenic callus cultures from young male flower buds on MS medium with 0.22 µM BA and 1.14 µM IAA; ***b***, Squash preparation of embryogenic callus showing globular stage embryo; ***c***, Germination of somatic embryos on 1/2 MS medium + 0.5 g/l ME and 0.1% AC; ***d***, A somatic embryo derived plantlet with good root system; and ***e***, Regenerated plants in paper cups with soilrite in the greenhouse.

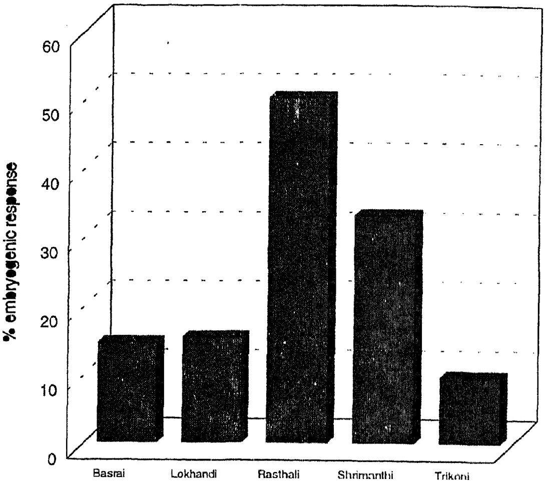
passage of four weeks. Embryogenic callus cultured on MS medium + 0.22 μM BA + 1.14 μM IAA with either 3% sucrose or 3% mannitol showed differences in callus morphology. The medium with 3% sucrose induced rapid proliferation of semi-friable embryogenic callus (90–95%), while with mannitol, the callus became nodular and compact (60–65%).

Five cultivars tested for embryogenic callus formation showed differential culture response (Figure 2). Rasthali was found to be highly responsive (50%) followed by 30% in Shreemanti. The other cultivars Basrai, Lokhandi and Trikoni were less responsive (8–15%). Embryogenic cultures of cv. Rasthali were maintained for a period of over 2 years without any decline in the capacity for proliferation. For the conversion of somatic embryos, the MS medium supplemented with 0.1% yeast extract, 1 g/l caesin hydrolysate (CH) and 1 g/l maltose was tested, either with agar or gelrite as the gelling agent. While the medium gelled with gelrite (0.2%) induced the formation of compact callus and globular embryos, the medium with agar (0.8%) showed > 80% browning of cultures.

Somatic embryos developed into plantlets (5–8%) on ½ strength MS basal medium without any growth regulators supplemented with 0.5% ME + 0.1% AC and gelled with 0.2% gelrite. Green plumule emerged from the embryos followed by the development of roots (Figures 1 *c*, *d*) within a span of 6 to 8 weeks. Plantlets developed normally when transplanted into paper cups with soilrite (Figure 1 *e*) in the greenhouse and 24 well-grown plants were transferred to the field.

Young floral tissues are known to be conducive to *in vitro* culture with good embryogenic potential[12]. In the present study, young male flower primordia of banana were used for the induction of embryogenic callus and somatic embryos which required different hormonal treatments. Inductive treatments included three auxins (IAA, NAA and 2,4-D) while a cytokinin with auxin (BA + IAA) was necessary for embryogenic callus proliferation and somatic embryo development. Navarro *et al.*[6] also noted that three auxins were essentially required for induction. Among the cultivars with different genomic backgrounds, Rasthali (AAB) showed good embryogenic response over Basrai (AAA) and Shreemanti (AAA) and others with AAA genome. A similar genotypic difference in culture response was observed in cultivars with AAA, AAB and ABB genomic status[5].

In the present study, embryogenic callus exhibited rapid proliferation on a medium with BA + IAA, with embryos developing on the callus surface. Several embryogenic cell clumps and globular stage embryos were observed while some developed into somatic embryos. Escalant *et al.*[5] also observed white, translucent callus and somatic embryos in cultures of young male flowers of cv. Grande Naine (AAA). Multiplication and maintenance of embryogenic cultures was achieved by culturing somatic embryos in a temporary immersion system, while Novak *et al.*[2] and Dheda *et al.*[3] described a liquid phase for the development of somatic embryos. In our studies, however, a liquid phase for somatic embryogenesis was not essential. Inclusion of mannitol (in addition to sucrose) in the medium is known to induce osmotic stress and embryogenic cultures were obtained in rice[13]. However, in this study, with the inclusion of mannitol, primary callus became nodular and more compact than on the sucrose medium.



An average of 96 cultures obtained from four replications of 24 each.

Figure 2. Frequency of embryogenic callus formation from young male flower buds in different cultivars of banana.

The development of an *in vitro* regeneration system is essential for studies related to genetic manipulation of banana. The embryogenic culture system described in this paper demonstrates the potentiality of the male flower bud explants for use in raising highly proliferative, embryogenic cultures for banana cultivars. Cultivar Rasthali, responding better *in vitro*, has fruits with sweet taste and thin peel but is highly susceptible to *Fusarium* wilt. Developing protocols for *in vitro* plant regeneration may aid efforts in the selection of disease-resistant clones. Separate media manipulations for embryo maturation were not required as the embryos developed into plantlets on the same medium making the culture system much simpler. Although, the plant conversion rates are low, we believe that further refinement in the media would lead to enhanced embryo to plant conversion frequency. Further exploitation of the system of somatic embryogenesis for mass propagation, artificial seeds and for generating transgenic plants may provide a significant step in the improvement of banana.

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RESEARCH COMMUNICATIONS

Cytochrome P-450 in drug-resistant *Mycobacterium tuberculosis*

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Methods for the isolation and spectrophotometric determination of cytochrome P-450 in mycobacteria were standardized. Cytochrome P-450 levels were estimated in *Mycobacterium tuberculosis* organisms sensitive to both isoniazid and rifampicin and resistant to any of the two drugs. Cytochrome P-450 was isolated and its presence was shown in *M. smegmatis*, *M. fortuitum*, *M. chelonae* and *M. tuberculosis* $H_{37}Rv$. The cytochrome P-450 content was significantly elevated in *M. tuberculosis*, resistant to both isoniazid and rifampicin when compared with the corresponding sensitive strains. It therefore appears that cytochrome P-450 might play a role in causing drug resistance in tuberculosis.

TUBERCULOSIS is one of the most alarming infectious diseases facing the world today, particularly with the advent of multi-drug resistant organisms. Bacteria develop resistance to drugs via a limited number of mechanisms[1], some of which apply to mycobacterial drug resistance[2] and this appears to be a multi-locus phenomenon and several factors contribute to the development of resistance. The role of drug-deactivating enzymes in the development of drug resistance is well established in bacteria[3] and insects[4]. This phenomenon usually involves increased activity of a particular enzyme responsible for degrading the active drug.

Cytochrome P-450, earlier referred to as the CO-binding pigment, was first described by Klingenberg[5]. It belongs to a group of hemoproteins and forms a vital component of the mixed-function oxidase system of the endoplasmic reticulum. Cytochrome P-450 constitutes the most powerful oxidizing enzymes and is involved in the metabolism and biotransformation of a wide variety of drugs and endogenous compounds. It is found in abundance not only in the hepatic microsomes, but also in the microsomes and mitochondria from the adrenal cortex. The hemoprotein is found in liver microsomes of a variety of vertebrates, including mammals, birds, snakes, frogs and fishes, plants, bacteria[6], bacteroids[7] and yeast[8].

An association between drug resistance and cytochrome P-450 drug-metabolizing enzyme activity has been reported in certain species of Plasmodium[9,10], *Drosophila melanogaster*[11], *Musca domestica*[12], *Trypanosoma cruzi*[13], *Leishmania mexicana*[14], *Heliothis virescens*[15], *Lucilia cuprina*[16], certain Candida species[17-19], *Cryptococcus neoformans*[20], etc. In all these studies, it has been clearly shown that the resistant species had elevated levels of cytochrome P-450 than the corresponding sensitive ones. Indirect evidence relating to mechanism of resistance in *M. avium* with respect to quinolones has been shown to be associated with bacterial P-450 activity[21]. For example, the resistant strains might have enhanced P-450 activity in the periplasm, resulting in an increased rate of metabolism of quinolones, which, therefore, cannot reach the critical concentration needed to be effective. However, when cytochrome P-450 is inactivated, the resistance mechanism gets defeated.

Recently the complete genomic sequence of *M. tuberculosis* has been reported by Cole *et al.*[22]. A large

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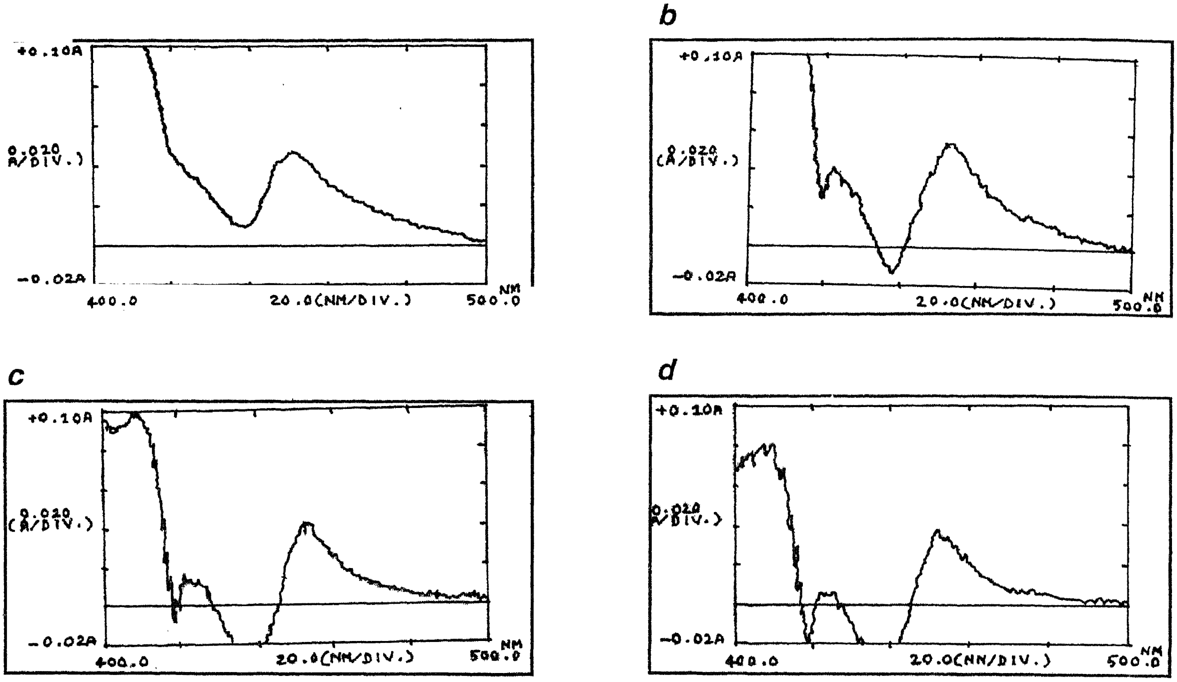

Figure 1. Spectral activity of cytochrome P-450 in different mycobacteria, *a*, *M. smegmatis*; *b*, *M. tuberculosis* $H_{37}Rv$; *c*, *M. fortuitum*; *d*, *M. chelonae*. The experiments were repeated on three different occasions with different batches of bacteria.

number of oxygenases containing cytochrome P-450 have been predicted to be present in *M. tuberculosis* and about 22 genes coding for cytochrome P-450 have been identified. However, an association between cytochrome P-450 and drug resistance in mycobacteria has not been studied. It was therefore decided to isolate this protein in certain mycobacterial species and estimate its content in *M. tuberculosis* strains, sensitive and resistant to certain anti-tuberculosis drugs, to see its possible involvement in causing drug resistance in tuberculosis.

The mycobacterial strains used for isolation of cytochrome P-450 were *M. smegmatis* (ATCC607), *M. tuberculosis* $H_{37}Rv$ (standard strain), *M. fortuitum* (TMC 1529) and *M. chelonae* (clinical isolate). Clinical isolates of *M. tuberculosis* strains, resistant to isoniazid alone ($n = 12$) and resistant to rifampicin and isoniazid ($n = 9$) were also used. The drug sensitivity pattern was determined by the indirect drug sensitivity test.

DNaseI and PMSF from Sigma Chemical Co. USA, sodium dithionite from Riedel-DeHaan Ag. Sealze, Hannover, β-mercaptoethanol from Fluka Buchs, Switzerland and lysozyme from Hi-media, India, were used for the above experiments. All other chemicals used were of analytical grade.

The organisms were maintained on LJ Slopes by regular subculturing. For experimental purposes, they were grown in modified Sauton's medium at 37°C. The cells were harvested during the log phase. The wet weight of the cells was determined.

Since cytochrome P-450 is a membrane-bound protein, the membranous fraction of the bacteria (sensitive and resistant strains) was prepared as follows: A 100% suspension of the cells was prepared in 10 mM potassium phosphate buffer pH 7.4. The cells were treated with lysozyme in the presence of a protease inhibitor namely, phenyl methyl sulfonyl fluoride (PMSF) and lysed by extensive sonication for about 20 min. The sonicate was treated with DNaseI (10 mg/ml) and further sonicated for 10 min. The cell suspension was centrifuged at 6000 rpm for 15 min to get rid of the cell debris. The resultant supernatant was again centrifuged at 40,000 rpm for 60 min. The pellet was washed with 10 mM potassium phosphate buffer pH 7.4 and suspended in the same buffer containing 1 mM EDTA, 20% glycerol, 100 mM PMSF and β-mercaptoethanol.

Cytochrome P-450 was determined according to the method of Omura and Sato[23]. In brief, the samples were suitably diluted in 10 mM potassium phosphate buffer pH 7.4. Equal volumes of the diluted sample were taken into two test tubes marked 'blank' and 'test'. A few grains of sodium dithionite were added to both the tubes. Carbon monoxide gas was bubbled into the tube marked 'test'. The contents of both the test tubes were then transferred into two matched cuvettes and the spectrum was recorded between 500 and 400 nm in a double-beam spectrophotometer (ATI Unicam). The protein content in the pellet was determined by the method of Lowry *et al.*[24].

A distinct peak at 450 nm was obtained in the membranous pellet in all the mycobacterial species tested (Figure 1 *a–d*). The presence of cytochrome P-450 in *M. smegmatis*, *M. tuberculosis* $H_{37}Rv$, *M. fortuitum* and *M. chelonae* was thus established. The quantity of cytochrome P-450 in the pellets of the different organisms was calculated from the difference in the optical density between 450 and 490 nm and using the molar extinction coefficient of 91 mM^{-1} cm^{-1}. Table 1 gives the quantity of cytochrome P-450 present in the various avirulent and virulent mycobacterial species.

M. tuberculosis $H_{37}Rv$, sensitive to isoniazid and rifampicin ($n = 12$) were processed simultaneously along with resistant bacteria. Clinical isolates of *M. tuberculosis* strains, resistant to isoniazid alone ($n = 12$) and resistant to isoniazid and rifampicin ($n = 9$) were processed for the cytochrome P-450 content. Table 2 gives the hemoprotein levels in these strains. The isoniazid-resistant organisms had a more than 2-fold increase in the P-450 content when compared to the sensitive bacteria. A similar trend was seen in the isoniazid and rifampicin-resistant bacteria too. The differences in the cytochrome P-450 content between the sensitive and both the resistant bacteria were highly significant ($P < 0.001$) (Figure 2).

Table 1. Quantity of cytochrome P-450 present in the various mycobacterial species

Organism	Mean (range)* Cytochrome P-450 (nmol/mg protein)
M. smegmatis	0.39 (0.19–0.78)
M. tuberculosis $H_{37}Rv$	0.60 (0.44–0.97)
M. fortuitum	0.30 (0.22–0.49)
M. chelonae	0.47 (0.29–0.60)

*Mean of 3 experiments.

Table 2. Cytochrome P-450 content in drug resistant and sensitive bacteria

Organism (*M. tuberculosis*)		Cytochrome P-450 (nmol/mg protein) mean ± SD
H- and R-sensitive	12	0.64 ± 0.24
H-resistant	12	1.55 ± 0.31
H- and R-resistant	9	1.05 ± 0.32

H, isoniazid; R, rifampicin.

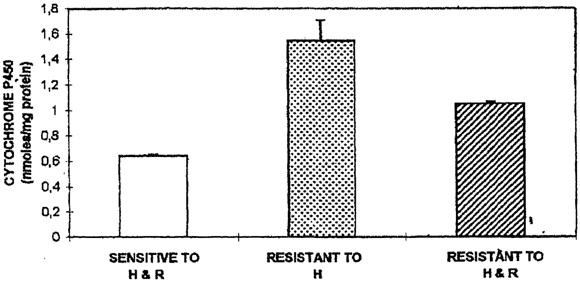

Figure 2. Cytochrome P-450 levels in drug sensitive and resistant *M. tuberculosis*. *M. tuberculosis* $H_{37}Rv$ sensitive to H and R ($n = 12$), *M. tuberculosis*, resistant to H ($n = 12$) and resistant to H and R ($n = 9$) were processed. H, isoniazid; R, rifampicin.

Although mutations in the *katG* (ref. 25), *inhA* (ref. 26) and *ahpC* genes[27] have been associated with resistance to isoniazid, the exact mode of action of isoniazid is not known. Likewise mutation in the *rpoB* gene that codes for RNA polymerase has been reported to be the cause of resistance to rifampicin[28]. However, some bacterial strains with low to intermediate resistance to rifampicin have been noticed with the *rpoB* gene intact, suggesting that there may be other cellular components which are able to mutate and confer a degree of resistance[29]. Studies conducted on rifampicin resistance in *Neisseria meningitidis* suggest that different levels of resistance to rifampicin can be imparted by mechanisms other than mutations in the *rpoB* gene[30].

The results reported here, i.e. elevated levels of cytochrome P-450 in isoniazid and rifampicin-resistant *M. tuberculosis* than the corresponding sensitive bacteria are similar to those reported in various other living species. Enhanced elimination of drugs by detoxification and metabolic pathways mediated by cytochrome P-450 is more likely to be responsible for increased resistance to the drug. Since the metabolism of isoniazid and rifampicin is cytochrome P-450-mediated, it is logical to assume that development of resistance to these drugs could possibly be due to increased cytochrome P-450 content in the bacteria. Moreover, an isoniazid-inactivating substance has been isolated from isoniazid-resistant avian mycobacteria which decomposed isoniazid to hydrazine and isonicotinic acid[31]. In a study conducted to see the effect of chronic retrovirus infection in the P-450-mediated activation of acetaminophen in mouse liver microsomes, it was observed that enhanced resistance to acetaminophen-induced hepatotoxicity could be due to increased excretion of the drug by P-450 mediated metabolic pathways[32]. In another study, patients with acute promyelocytic leukemia treated with retinoic acid, developed resistance to retinoic acid despite an initial good response[33]. One potential mechanism for clinical retinoic acid resistance is the pharmacologic alteration in the metabolism of retinoic acid. Induction of cytochrome P-450 resulted in lower plasma and cellular levels of active retinoids. Thus, acquired resistance to retinoic acid may be explained at least in part by drug metabolism in leukemic cells.

In an *in vitro* study carried out to assess the anti-*M. avium* activities of quinolones, it was found that a cyclopropyl group substituted at the N1 position of a quinolone is crucial against all of the resistant *M. avium* strains but not the susceptible ones[21]. For example, resistant strains might have enhanced P-450 activity in the periplasm, resulting in an increased rate of metabolism of quinolones, which therefore cannot reach the critical concentration needed to be effective. The substituted group induces suicidal inactivation of the metabolizing enzyme namely, cytochrome P-450, which in turn reduces its activity and defeats the resistance mechanism.

It therefore appears that cytochrome P-450 also plays a role in causing drug resistance in *M. tuberculosis*. It would be of interest to study the isoform pattern of cytochrome P-450 in isoniazid and rifampicin resistant *M. tuberculosis* and compare the findings with the sensitive organism. This might throw light on whether different isoforms of cytochrome P-450 exist in drug-sensitive and resistant bacteria. Attempts on these lines are in active progress.

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Binding and conformation of denatured horseradish peroxidase during *E. coli* ribosome mediated folding

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Denatured horseradish peroxidase (HRP) refolded in the presence of intact 70S *E. coli* ribosome. Fluorescence spectroscopic evidence of direct physical association between the ribosome particles and the denatured HRP during refolding has been detected. The efficiency of energy transfer from the single tryptophan (Trp) to the heme moiety and the quenching patterns of the Trp fluorescence by iodide and acrylamide differed with time while folding in the presence and absence of ribosome. An estimate of the binding of denatured fluorescein-conjugated HRP with ribosome was obtained from polarization measurements (K_d = 41 nM).

FOLDING of denatured proteins to their biologically active forms has been shown to be assisted by a class of proteins collectively known as the molecular chaperones[1,2]. We have previously shown that ribosomes from *E. coli* could fold a large number of proteins to their active forms when denatured with 6 M guanidinium chloride (GdmCl) prior to incubation with ribosomes[3,4]. Subsequently it was found that the protein folding activity remained in the 50S subunit and the 23S rRNA of the *E. coli* ribosome. The 30S subunit and the 16S rRNA were devoid of such activity[4] and the protein folding activity in the 23S rRNA could be inhibited by the antibiotics, chloramphenicol and erythromycin which interact with the large loop of domain V of the 23S rRNA[5,6]. These observations were later confirmed by Hardesty and coworkers[7]. In the present study we have detected the physical association between denatured horseradish peroxidase (HRP) and the intact 70S ribosomes from *E. coli* in the course of ribosome-assisted folding. We have also determined the affinity constant of the association of the 70S ribosome with the denatured fluorescein-conjugated HRP.

The folding pathways in the monomeric protein, HRP and its interaction with the denaturant, GdmCl, are well studied[8,9]. HRP contains a single tryptophan (Trp) residue and the heme moiety[10,11], an intrinsic fluorescence energy transfer acceptor[12], making HRP suitable for fluorescence spectroscopic studies. The time-dependent changes in proximity between the Trp residue and the heme moiety were different when denatured HRP was allowed to refold in the absence and presence of ribosomes. The acrylamide and iodide quenching behaviour, used as an index of overall conformation of different states of the protein after refolding in the presence and absence of ribosome, also indicated that the denatured HRP after ribosome-assisted folding assumed conformation similar to that of the native HRP.

HRP (Type VI, Sigma) at a concentration of 44 μM was incubated with 6 M GdmCl at 22°C for 2.5 h for denaturation. Refolding was initiated by 40-fold dilution of the denatured HRP in the buffer containing 20 mM Tris-HCl, 50 mM KCl, 10 mM $MgCl_2$, pH 7.5, with or without ribosome. After 30 min of refolding at 22°C the enzyme was assayed in 0.1 M phosphate buffer, pH 6.0 with 0.005% freshly prepared solution of *o*-dianisidine and 2.2 mM hydrogen peroxide[13,14]. The mixture was incubated with the enzyme for 3 min at 20°C and the absorbance of the coloured solution was measured at 460 nm. 70S ribosomes were purified from *E. coli* MRE 600 cells, which has been described in our earlier publications[4,15]. HRP concentration was determined spectrophotometrically[9]. An HRP concentration of 1.1 μM and 0.015 μM of ribosome was used throughout the course of study in a final volume of 0.8 ml, unless otherwise mentioned.

Denaturation of HRP by 6 M GdmCl was associated with ~30% enhancement in fluorescence intensity (Figure 1). The emission maximum was red-shifted from 342 nm to 356 nm upon denaturation in 6M GdmCl. Figure 1 also shows the fluorescence spectrum of 70S ribosome preparation from *E. coli*. Both enhancement in fluorescence intensity and red shift occurred immediately after mixing the denaturant with HRP. Removal of GdmCl by 40-fold dilution restored the emission maximum immediately back to 345 nm and the fluorescence slowly quenched up to ~25% in 15–20 min before reaching a plateau. It has been reported that heme dissociates from the holo-enzyme when HRP was denatured by overnight incubation in 6 M GdmCl (ref. 8). However, in our denaturing condition there was no dissociation of heme as indicated from absorbance measurements of both native and denatured HRP in the Soret region with a maximum absorption at 402 nm. CD spectra of native and denatured HRP have been reported earlier[9]. The loss of secondary stucture was complete in less than 5 min as indicated by the decrease in the negative peak at 222 nm (not shown). No further change was observed after incubation for 3 h. The steady-state fluorescence was measured in a Hitachi F3010 spectrofluorometer using 10 mm pathlength quartz cuvettes. Trp fluorescence was measured upon excitation at a

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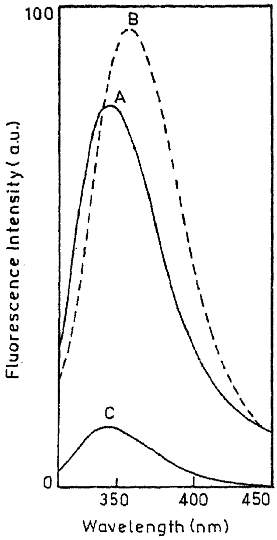

Figure 1. Fluorescence emission spectra of native HRP, 1.3 μM (A); denatured HRP in presence of 6M GdmCl (B); and 70S ribosome from *E. coli*, 0.02 μM (C).

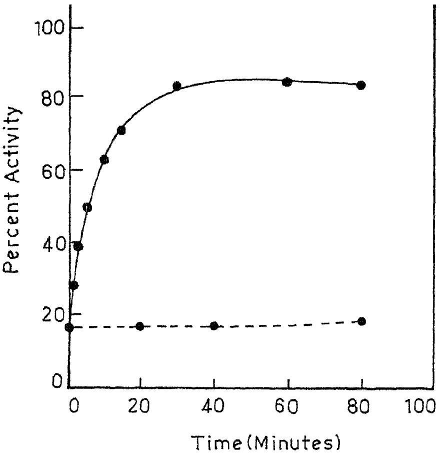

Figure 2. Time-dependent reactivation of enzymic activity during ribosome-assisted folding (solid line) and folding of denatured HRP in the absence of ribosomes (dotted line). Denatured HRP (0.8 μM) was reactivated with or without ribosomes (0.2 μM) for different times as indicated in the abscissa prior to assay.

wavelength of 295 nm. A nominal bandwidth of 5 nm and 10 nm for the excitation and emission slits, respectively, were used for measurements. Only ~ 10% self-quenching of ribosomal fluorescence was observed over a time-period of one hour with no change in the 90° light scattering. Sample temperature was maintained at 22°C.

Denatured HRP was diluted 40-fold in the buffer containing 70S ribosome, incubated for different times and assayed at 20°C, the optimum temperature for its activity. Figure 2 shows time-dependent reactivation of denatured HRP in the presence and absence of *E. coli* ribosome.

The Forster type of fluorescence resonance energy transfer[16,17] has been shown to be useful in measuring distances in the range of 10 to 60 Å. The efficiency of transfer, *E*, from the donor Trp to the acceptor heme is defined by,

$$E = 1 - F_{\mathrm{DA}}/F_{\mathrm{D}}, \qquad (1)$$

where F_{DA} and F_{D} are fluorescence intensities of the donor at 345 nm in the presence and absence of the acceptor respectively. From *E*, the distance between the donor and the acceptor, *r*, can be calculated using the following expression,

$$E = R_0^6/(r^6 + R_0^6), \qquad (2)$$

where R_0 is the distance at which $E = 0.5$. R_0 for Trp and heme in HRP has been previously determined[12] to be 24 Å.

Time-dependent changes in HRP fluorescence in the presence of ribosome particles were monitored at different time-points by spectral subtraction of ribosome from the mixture of HRP and ribosome. The ribosome concentration chosen was found to impart no inner filter effect. The control spectrum of denatured HRP, for the measurement of F_{D} was obtained after immediate dilution of 6M GdmCl-treated HRP in buffer without ribosome. During the process of refolding, Trp fluorescence of denatured HRP quenched with time both in the presence and absence of ribosome. Quenching of fluorescence from the single Trp residue of the denatured HRP was attributed to energy transfer from Trp to the heme. Such time-dependent quenching of fluorescence during ribosome mediated folding of denatured HRP is shown in Figure 3. Fluorescence emission spectra, upon subtracting the contribution of ribosome, are shown at each of the time-points and used for the measurement of F_{DA}. Contribution from the change in ribosomal fluorescence, if any, was neglected because of the weak fluorescence signal from 70S ribosome (Figure 1) compared to HRP. The blue-shift in the emission maximum from 356 nm to 345 nm occurred immediately when the denatured enzyme was diluted 40-fold to initiate refolding both in the presence and absence of ribosomes. No further change in the position of the emission maxima was observed during 30 min of refolding. Fluorescence intensity at 345 nm was used for the evaluation of *E*. The efficiencies of transfer (*E*) and the distances (*r*) between the Trp and heme were evaluated from eqs (1) and (2) respectively at different time-points during the folding of

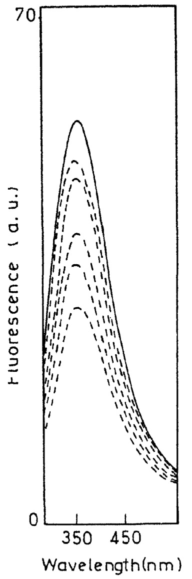

Figure 3. Tryptophan fluorescence spectra of denatured HRP (1.1 μM) at different time-points in the presence of 70S ribosome (0.015 μM). The top spectra in solid line is the control in the absence of ribosome. Corrected fluorescence emission spectra in dashed lines correspond to the same at different time-points (from top to bottom) of 5, 10, 15, 20 and 30 min respectively, in the presence of ribosomes.

Table 1. Energy transfer efficiencies and estimated distances between Trp and heme at different time-points

Trp/Heme in HRP	$E_{2\ \mathrm{min}}$	E_{10}	$E_{20\ \mathrm{min}}$	$E_{30\ \mathrm{min}}$
Unassisted folding of denatured HRP in absence of ribosome	0.029 (43.1 Å)	0.196 (30.4 Å)	0.270 (28.3 Å)	0.272 (28.3 Å)
Ribosome-assisted folding of denatured HRP	0.024 (44.5 Å)	0.143 (32.3 Å)	0.357 (26.5 Å)	0.470 (24.4 Å)

Values in parenthesis are distances between Trp and heme in HRP during the process of refolding; *E* is the efficiency of energy transfer.

denatured HRP in the presence and absence of 70S ribosomes. *E* and *r* values are summarized in Table 1.

Amino acid sequence of horseradish peroxidase revealed the single Trp positioned at 117th residue from the N-terminus. As the X-ray structure of HRP was not available, the structural model of the protein was built by aligning the amino acid sequence of HRP on that of yeast cytochrome c peroxidase[18]. The model consists of two domains of the peroxidase enclosing the central heme prosthetic group. Of the 10 helical regions (35% overall helicity), two heme-attached helices include the proximal His and three proposed distal catalytic residues Arg, His and the Trp. More recently, the structural model has been refined by energy minimization and molecular dynamics calculations[19]. From energy transfer measurements we have determined a distance of 24.4 Å between Trp and heme when the denatured HRP was refolded for 30 min in the presence of ribosome restoring biochemical activity in the enzyme. The distance between the Trp and heme was ~ 44 Å in the denatured enzyme, measured at the earliest time-point after the initiation of folding by the 40-fold dilution of 6M GdmCl. On the other hand, Trp and heme were 28.3 Å apart when denatured HRP was refolded in the absence of ribosome showing poor biochemical activity in the enzyme (Figure 2). The data on energy transfer efficiency and distances between Trp and heme are summarized in Table 1.

Binding of denatured fluorescein-conjugated HRP (Sigma) with intact 70S ribosome particles was monitored by measuring the increase in fluorescein polarization with increasing concentrations of the ribosomes. A fixed concentration of the denatured fluorescein-HRP was added to different increasing concentrations of ribosomes and the polarization parameters were quickly measured. The ribosomes showed no detectable absorbance at 495 nm. The scatter contributions were subtracted from each data-point. For polarization measurements with fluorescein-conjugated HRP (EX: 495 nm; EM: 515 nm), excitation and emission slits with a nominal bandpass of 3 nm and 5 nm respectively were used. Polarization measurements were performed using Hitachi polarization accessory. An estimate of binding between the 70S particle and denatured HRP was obtained by measuring the increase in fluorescein polarization of fluorescein-conjugated HRP with increasing concentration of 70S ribosomes (Figure 4). The apparent (K_d) of binding of denatured fluorescein-HRP with 70S ribosomes, obtained from the concentra-

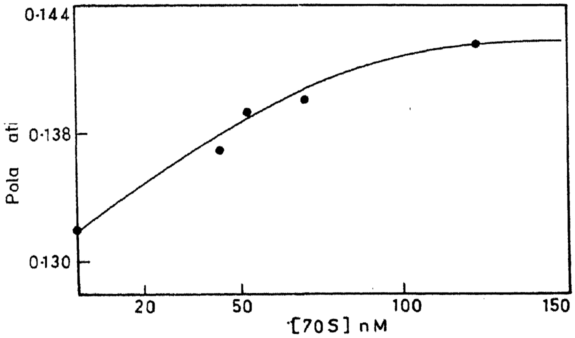

Figure 4. Change in fluorescein polarization in denatured fluorescein-conjugated HRP (1.0 μM) upon interaction with *E. coli* ribosomes. The concentration of 70S ribosomes corresponding to the 50% change in the total amplitude determines the K_d being 41 nM.

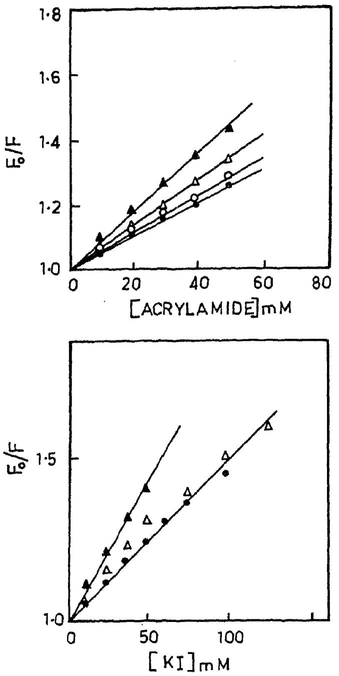

Figure 5. Stern–Volmer plots of acrylamide and iodide quenching of Trp fluorescence of native and denatured HRP (1.1 μM). The figure shows plots of F_0/F against concentration of acrylamide and iodide in the native HRP (●); native HRP after 30 min incubation with ribosomes (O); and denatured HRP after 30 min refolding in absence (▲); and presence (Δ) of ribosomes.

tion corresponding to the 50% change in the total amplitude was 41 nM.

The emission intensities of HRP both in the presence and absence of ribosome in 20 mM Tris-HCl, 10 mM $MgCl_2$, 50 mM KCl, pH 7.5 were measured as a function of increased concentration of acrylamide and iodide which are widely used as quenchers of Trp fluorescence[17]. For iodide quenching experiments the same buffer contained 2 mM sodium thiosulphate in order to prevent the formation of I_3^-. The fluorescence intensity in the absence of acrylamide and iodide (F_0) was quenched by increasing concentration of both the quenchers (F), as shown in Figure 5. The linear range of the plot of F_0/F versus the final quencher concentration (Stern–Volmer plot) shows that the extent of quenching was larger in case of denatured HRP after refolding in the absence of ribosomes. The quenching pattern of the denatured protein after ribosome-assisted folding and a mixture of the native HRP and ribosomes was similar to that of the native HRP. No quenching in ribosomal fluorescence was observed using either acrylamide and iodide. The quenching experiments indicated that the denatured HRP assumes native conformation after ribosome-assisted folding. Refolding in the absence of ribosomes led denatured HRP to assume a misfolded non-native conformation as indicated by the larger extent of quenching by both acrylamide and iodide along with the marked decrease in the enzymic activity.

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Development of isonuclear male sterile lines with four different cytoplasmic backgrounds in rice

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For the first time in rice, four cytoplasmic genetic male sterile (CMS) lines with different cytoplasmic backgrounds, namely, Wild abortive, *Oryza perennis* (through conversion), Kalinga I, and Lalruma (through *indica/indica* hybridization) were developed by repeated backcrossing with a common isonuclear maintainer, cultivar (cv.) Krishna. These four new CMS lines with a common nuclear background were confirmed to be cytoplasmically different from one another.

THE importance of the use of cytoplasmic genetic male sterile (CMS) line in the development of hybrid rice in a three-line system is well known to the breeders. With this objective in view, the first CMS line in a self-pollinated crop like rice was developed in China from a male sterile plant (*Oryza sativa* f. *spontanea*), designated as Wild abortive (WA) (ref. 1). Subsequently, even though more CMS lines from different sources were developed in China[2], none of these were found suitable for the diverse climatic conditions in countries outside China. Therefore, a number of male sterile lines have been developed from various accessions of cultivated and wild rices at the International Rice Research Institute (IRRI), Philippines, and elsewhere[2-5]. However, the cytoplasmic genetic male sterile system used extensively to develop commercial hybrid rice in China and India has been mainly developed from a wild abortive (WA) cytoplasmic source. Intensive use of a single source of male sterile cytoplasm in developing hybrids is considered disastrous, as was the case with Texas cytoplasm in maize[6]. Virtually all major crops, including rice, have a narrow genetic base, and consequently are vulnerable to virulent diseases, insects or erratic climatic factors.

Therefore, it was considered important to diversify the sources of male sterile cytoplasm and to develop new CMS lines of WA cytoplasm for hybrid rice breeding in India. However, lack of efficient techniques to characterize CMS sources as well as nonavailability of effective restorers for CMS lines, are two major problems. With this objective in view, four CMS lines with different cytoplasmic backgrounds (Wild abortive, *O. perennis*, Kalinga I, and Lalruma) were developed by repeated backcrossing with a common isonuclear maintainer cv. Krishna, and characterization of the cytoplasmic sources was established by interaction of these CMS lines with elite lines.

The two CMS lines Krishna A with WA cytoplasm and Krishna A with *O. perennis* cytoplasm were developed through conversion involving the CMS lines V20A (WA) and IR 66707A (*O. perennis*), respectively, by recurrent backcrossing to a common isonuclear maintainer, Krishna (as the pollen parent). The CMS line Krishna A with Kalinga I cytoplasm was developed through *indica/indica* hybridization[7], and by repeated backcrossing with the pollen parent, Krishna. However, for the development of the Krishna CMS line with Lalruma (*indica*) cytoplasm, 36 crosses and their reciprocals were attempted using land races and improved high-yielding varieties. Completely sterile plants of the F_1 cross Lalruma/Krishna, which showed high reciprocal differences for pollen and spikelet sterility, were selected and backcrossed to their respective male and female parents. The backcross population (Lalruma/Krishna)/Krishna which showed complete pollen and spikelet sterility in BC_1 was further backcrossed to the recurrent male parent, Krishna, up to the sixth backcross generation (BC_6).

To understand the nature of these four sterile cytoplasms, these were testcrossed with three maintainers, namely, V20B (maintainer of WA), Yar-Ai-ZhaoB (maintainer of Gambiaca), and MS 577B (maintainer of *O. sativa* f. *spontanea*) and five lowland elite lines, namely, IR 48725-B-B-120, SPR 7210-1-3, NDR 30074, TTB 150-61-2-1, and R 657-93-869. All the crosses were evaluated for their pollen and spikelet sterility/fertility. Pollen grains were stained with iodine-potassium iodide solution (I-KI) and examined under the microscope for determining the pollen sterility. Morphological features like plant height, flowering duration, ear bearing tillers (EBT), panicle length and exsertion, and number of spikelet per panicle were recorded for 20 plants.

The F_1 crosses of V20A/Krishna, and IR 66707A/Krishna showed complete pollen sterility with no seed set. Completely sterile F_1 plants of these two crosses were utilized for the development of new CMS lines Krishna A with wild abortive cytoplasm and Krishna A with *O. perennis* cytoplasms by repeated backcrossing with a common isonuclear maintainer, Krishna. Complete pollen sterility with no seed set was noticed in all the backcross generations (BC_1 to BC_6).

The F_1 cross Kalinga I/Krishna showed complete sterility with high reciprocal difference[7]. The sterile F_1 plants were repeatedly backcrossed to the recurrent male parent, Krishna[7], up to the BC_6 generation and then complete sterile Krishna A with Kalinga I cytoplasm were developed, which showed cold tolerance during seedling stage.

Out of the 36 crosses of *indica* (land races)/*indica* (improved high yielding varieties), complete pollen and spikelet sterility was observed in the F_1 plants of cross Lalruma/Krishna with high reciprocal difference, i.e. its

Table 1. Pollen sterility and spikelet fertility percentage in parents, F_1, backcrosses and reciprocal of the CMS line Krishna A derived from Lalruma (*indica* rice)

Parents and cross combination	Generation	Pollen sterility (%)	Spikelet fertility (%)
Lalruma (*indica*)	P_1	5.8	92.1
Krishna (*indica*)	P_2	4.1	95.2
Lalruma/Krishna	F_1	100	0
Krishna/Lalruma	F_1	3.9	96.3
(Lalruma/Krishna)/Lalruma	BC_1P_1	29.8	67.8
(Lalruma/Krishna)/Krishna	BC_1P_2	100	0
(Lalruma/Krishna)/Krishna	BC_2P_2	100	0
	BC_3P_2	100	0
	BC_4P_2	100	0
	BC_5P_2	100	0
	BC_6P_2	100	0

Table 2. Pollen sterility and spikelet fertility (%) along with other characters of four CMS lines of Krishna A

CMS line	PH (cm)	EBT	FD (days)	PL (cm)	PE (cm)	PS (%)	SPP no.	SF (%)
Krishna A (WA)	56	23	89	21.6	11.0 (50.9%)	100	102	0
Krishna A (*O. perennis*)	49	24	97	20.3	8.6 (42.9%)	100	90	0
Krishna A (Kalinga I)	59	32	90	21.3	11.9 (55.9%)	100	109	0
Krishna A (Lalruma)	60	29	94	20.9	10.6 (50.7%)	100	112	0

Value of panicle exsertion in percentage in parenthesis.

PH, plant height; EBT, ear bearing tillers; FD, 50% flowering duration; PL, panicle length; PE, panicle exsertion; PS, pollen sterility; SPP, spikelet per panicle; SF, spikelet fertility.

reciprocal cross Krishna/Lalruma showed high fertility (both pollen and spikelet) (Table 1). Similarly, high F_1 sterility was observed in most of the *indica/indica* crosses where Pankhari 203 was involved as the male parent[8].

Completely sterile F_1 plants of Lalruma/Krishna were backcrossed to both its parents. In the backcross BC_1P_1, sterility decreased, when the female parent Lalruma was used as the recurrent male parent. However, when the male parent Krishna was backcrossed to the F_1 plants as the recurrent parent, complete sterility was observed in BC_1P_2 (Table 1). Since all progenies in BC_1P_2 generation of the backcross (Lalruma/Krishna)/Krishna were found to be completely sterile, they were further backcrossed (up to BC_6) to the recurrent male parent Krishna, in order to develop Krishna-male-sterile-line with Lalruma cytoplasm. Results of these reciprocal backcrosses indicated the effects of cytoplasm in inducing male sterility, and have confirmed that Krishna with fertile cytoplasm maintains the sterility, while, Lalruma with sterile cytoplasm restores fertility. With the development of Krishna A with Lalruma cytoplasm, four CMS lines were developed possessing different cytoplasms, in the genetic background of a single rice cv., Krishna. This is the first report of development of isonuclear CMS lines possessing four different cytoplasmic backgrounds.

All the four CMS lines of Krishna A with different cytoplasmic sources (WA, *O. perennis*, Kalinga I, Lalruma) are dwarf in stature, of medium duration (Table 2), and have white shrivelled anthers with 80–90% unstained, withered, sterile (UWS) pollen grains; and the rest with unstained, spherical, sterile (USS), pollen grains.

To study the diversity among the four sterile cytoplasms, Krishna CMS lines were testcrossed with the three maintainers, namely, V20B, Yar-Ai-ZhaoB, MS 577B and with five lowland elite lines (Table 3). Results indicated that the male sterility of all these four CMS lines could be maintained effectively by V20B, Yar-Ai-ZhaoB, and MS 577B.

On the other hand, the results for the elite lines were: (i) IR 48725-B-B-120; while it restored the fertility effectively (> 80% spikelet fertility) in Krishna A (WA

Table 3. Pollen and spikelet fertility (%) in testcrosses between CMS (A)/maintainer (B) lines, and CMS (A)/lowland elite lines

Genotype	Krishna A (WA)	Krishna A (*O. perennis*)	Krishna A (Kalinga I)	Krishna A (Lalruma)
Maintainers				
V20B	0 (0)	0 (0)	0 (0)	0 (0)
Yar-Ali-ZhaoB	0 (0)	0 (0)	0 (0)	0 (0)
MS 577B	0 (0)	0 (0)	0 (0)	0 (0)
Lowland elite lines				
IR 48725 B-B-120	86.1 (82.8)	0 (0)	76.1 (74.9)	69.2 (66.7)
SPR 7210-1-3	92.9 (88.3)	0 (0)	0 (0)	0 (0)
NDR 30074	0 (0)	0 (0)	0 (0)	34.3 (27.2)
TTB 150-61-2-1	54.2 (40.7)	0 (0)	63.8 (53.9)	89.7 (81.2)
R 657-93-869	60.3 (42.2)	0 (0)	0 (0)	74.2 (56.2)

Value of spikelet fertility percentage in parenthesis.

cytoplasm) and partially (< 75% spikelet fertility) in Krishna A (Kalinga I cytoplasm), and Krishna A (Lalruma cytoplasm), it maintained the sterility effectively in Krishna A (*O. perennis* cytoplasm). (ii) SPR 7210-1-3; whereas it restored the fertility, effectively in Krishna A (WA cytoplasm), it maintained the sterility of the other three CMS lines, Krishna A (*O. perennis* cytoplasm), Krishna A (Kalinga I cytoplasm), and Krishna A (Lalruma cytoplasm). (iii) NDR 30074; maintained the male sterility in Krishna A (WA cytoplasm), Krishna A (*O. perennis*), and Krishna A (Kalinga I cytoplasm), but was a partial fertility restorer of Krishna A (Lalruma cytoplasm). (iv) TTB 150-61-2-1; while it restored the fertility effectively in Krishna A (Lalruma cytoplasm), it was a partial restorer of Krishna A (WA cytoplasm), and Krishna A (Kalinga I cytoplasm), and maintained the male sterility in Krishna A (*O. perennis* cytoplasm). (v) R657-93-869; maintained effectively the male sterility of the two cytoplasmic sources, Krishna A (*O. perennis*) and Krishna A (Kalinga I), but restored the fertility partially in other two male sterile lines, Krishna A (WA cytoplasm) and Krishna A (Lalruma cytoplasm). However, none of the 5 lowland elite lines could restore the fertility of the Krishna A (*O. perennis* cytoplasm).

On the basis of our studies, since the four CMS lines interacted differently with each of the five lowland elite lines, despite their common nuclear background, we have concluded that the cytoplasmic factor(s), inducing male sterility, in these CMS lines were different from one another.

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Somatic embryogenesis and plant regeneration from immature anthers of *Hevea brasiliensis* (Muell.) Arg.

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High frequency somatic embryogenesis and plant regeneration were achieved from immature anthers of *Hevea brasiliensis* – the natural rubber-producing tree. Optimum callus induction was observed on modified Murashige and Skoog (MS) medium supplemented with 2.0 mg/l 2,4-D and 0.5 mg/l Kn. Subsequent culturing of callus on medium containing various concentrations and combinations of auxin/cytokinin, resulted in embryo induction. Maximum number of somatic embryos were produced on medium supplemented with 0.7 mg/l Kn and 0.2 mg/l NAA. Further development of the embryos into plantlets was achieved on a hormone-free medium. Cytological analysis revealed that all the plantlets tested were diploid. Plantlets transplanted to polybags were maintained under greenhouse conditions, and subsequently established in the field.

OVER the past two decades, considerable progress has been made on *in vitro* techniques for multiplication and improvement of *Hevea*. However, a protocol for large-scale commercial application has not yet been evolved[1]. Recently, there has been an increasing interest in the induction of somatic embryogenesis especially for use in genetic transformation. Somatic embryogenesis has been reported from anthers as well as inner integumental tissue[2–5]. However, the technique is still not sufficiently developed to be utilized in crop-improvement programmes. Reliable somatic embryo formation is limited to only a few genotypes of *Hevea*. Embryogenic capacity is fugacious, and the rate of conversion of the embryos to plantlets is very low[6]. Pollen-derived plants from 13 different clones have earlier been transplanted and established in the field[7]. However, while only a few clones exhibited a high frequency plantlet induction (22%), many clones exhibited a very low embryoid and plantlet regeneration rate and some clones did not show any embryoid induction at all[1]. To our knowledge no reports are available on plant regeneration from immature anthers for Indian clones of *H. brasiliensis* to date. The present study was therefore carried out for developing a reliable regeneration system from immature anthers via somatic embryogenesis for Indian clones of rubber, *H. brasiliensis*.

Floral buds (0.5–1.0 mm length) were collected from clone RRII 105 of *H. brasiliensis*. After ascertaining their developmental stage under microscope, they were surface-sterilized for 5 min with 0.5% sodium hypochlorite solution containing a few drops of Tween 20 followed by thorough washing with sterile water. Immature anthers at the diploid stage (before microsporogenesis) were dissected out aseptically, and 7–8 anthers were transferred into each tube. Effect of Murashige and Skoog[8] (MS) based medium and modified MS medium on callus induction was studied. MS medium was modified by lowering NH_4NO_3 to 1.0 gm/l and by replacing MS vitamins with B_5 (ref. 9) plus 5% sucrose. For callus induction, various auxins namely 2,4-dichlorophenoxyacetic acid (2,4-D), α-naphthaleneacetic acid (NAA), indol-3-butyric acid (IBA), indol-3-acetic acid (IAA) at 1.0 or 2.0 mg/l in combination with kinetin (Kn) at 0.5 or 1.0 mg/l were used. Effect of 2,4-D on callusing was further evaluated using modified MS basal medium supplemented with different concentrations of 2,4-D (0.0–3.0 mg/l) along with 0.5 mg/l Kn. Calli were then subcultured on embryo-induction medium (20 ml/tube) containing 7% sucrose and 0.2% activated charcoal fortified with different auxins in combination with Kn to investigate their effect on somatic embryogenesis.

After maturation, embryos were transferred to the same media containing 3% sucrose but without the hormones. All media were solidified with 0.21% gelrite and the pH was adjusted to 5.6 before autoclaving for 15 min at 121°C. For the induction of callus as well as the induction of embryo, cultures were incubated under dark at 25 ± 2°C and maintained in light for plant regeneration under a 16 h photoperiod ($40\ \mu E\ m^{-2}\ s^{-1}$) at 25 ± 2°C. Regenerated plants were planted in polybags and grown in greenhouse initially. Each experiment was repeated twice with 3 replications. Data on percentage of explants producing callus and embryos were based on visual observations. To analyse the factorial effect of NAA/Kn on embryo induction, analyses of variance were performed. Mean number of embryos were compared using LSD test. Cytological analyses were carried out to confirm the ploidy level of the regenerants, using the acetocarmine (2%) squash method.

In the present study, MS medium induced no callus formation even after 2 months of culturing of immature anthers in the presence of different auxins tested, except poor callusing was observed in presence of 2,4-D. However, Chen *et al.*[10] had previously reported callus induction in MS basal medium for *Hevea* anther culture. In this study, swelling of the explant was noticed on modified-MS medium, after 2 weeks of culture, followed by callus initiation between 40–50 days. Callus was obtained only when 2,4-D was added along with 0.5 mg/l

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Kn. Frequency of callus induction decreased with the increase in Kn level (1.0 mg/l). Other auxins, like IBA and IAA, resulted only in explant swelling and NAA showed a poor response. Both friable callus and compact callus could be obtained from the explants. However, the nature of friability and compactness differed depending upon 2,4-D concentration resulting in 3 types of callus: Type I, friable; Type II, less friable; and Type III, compact were obtained (Table 1). Similarly, friable callus and compact callus was observed on MH medium with 3,4-D/Kn by Etienne *et al.*[11]. Friable but loose or watery callus (Type I) was obtained when media contained low concentrations of 2,4-D. However, friability was reduced with an increase in 2,4-D concentration. The optimal concentrations of 2,4-D and Kn for embryogenic callusing were 2.0 mg/l and 0.5 mg/l, respectively. Pale yellow, compact aggregates of cells with a shiny surface and mucilaginous coat (Type II) were found on this combination. The percentage of callusing increased when the concentration of 2,4-D increased from 2.0–3.0 mg/l, but callus was nonembryogenic in nature (Type III).

Subculturing of Type II callus, initially changed to brownish colour, and subsequently yellow friable embryogenic callus was produced. Embryoids started to emerge from these callus cultures after 4–5 months of culturing in embryo-induction medium. The friable embryogenic callus, induced from Type II, displayed active morphogenic growth and asynchronous development of globular structures (Figure 1 *a*). Different stages of embryogenic organizations from globular, heart to cotyledonary stages were observed in the same medium (Figure 1 *b* and *c*). Compact callus was observed to show maximum embryogenic competence. While the histological studies (Montoro *et al.*[12]) revealed that compact callus showed high embryogenic competence in *Hevea*, in the present study although compact callus was most embryogenic, Type III callus sometimes remained as it was or produced callus with no embryogenic competence, thus suggesting that high concentrations of 2,4-D beyond 2.0 mg/l in the medium were inhibitory to embryogenesis. Type I callus also turned brownish and produced friable callus, but with no embryos. Montoro *et al.*[12] noticed that modifying the auxin/cytokinin balance resulted in the loss of embryogenic potential of the friable callus.

Table 1. Effect of 2,4-D and kinetin (Kn) on callus induction from immature anthers of *Hevea brasiliensis*

Growth regulators 2,4-D + Kn (mg/l)	Callus morphology	Callus type	Callus scoring
0.0 + 0.5	–	–	–
0.5 + 0.5	Friable, watery or wet, soft, white-creamy	Type I	+
1.0 + 0.5	Friable, little watery, soft, white-creamy	Type I	+
1.5 + 0.5	Less friable or compact, pale yellow	Type II	++
2.0 + 0.5	Compact, shiny surface, pale yellow	Type II	+++
2.5 + 0.5	Compact, hard or dry, pale yellow	Type III	+++
3.0 + 0.5	Compact, hard or dry, pale yellow	Type III	++++

Data were taken after two months of culturing on callus-induction media with modified MS basal media. Callus-induction frequency is expressed as follows:
+ = 1–20%; ++ = 21–50%; +++ = 51–80%; ++++ = 81–1

Table 2. Effect of different auxins in combination with Kn on the induction of somatic embryogenesis of *H. brasiliensis*

Growth regulator conc. (mg/l)		Nature of response		
		Callus browning	New calli proliferation	Embryo formation
2,4-D/Kn	0–0.4/0.5–1.0	less	70% FEC with fast growth	Infrequent development
IBA/Kn	0–0.4/0.5–1.0	abundant	20% FEC with slow growth	Sporadic formation
IAA/Kn	0–0.4/0.5–1.0	abundant	20% FEC with slow growth	Sporadic formation
NAA/Kn	0–0.4/0.5–1.0	moderate	40% FEC with slow growth	Frequent development

Observations were made after 4–5 months of culture in embryo induction medium and the results were noted; FEC = friable embryogenic callus.

Among the various auxins tested for embryogenesis, IAA and IBA influenced sporadic formation of embryos either singly or in clusters (Table 2). Incorporation of 2,4-D often led to embryogenic callus proliferation showing a tendency for embryogenic competence or rarely-formed globular embryos. However, these failed to develop further. NAA had a profound influence on embryogenesis in rubber. Table 3 shows the influence of 30 combinations of various concentrations of NAA and Kn on the number of somatic embryos formed. Among the 30 combinations used, embryogenesis was observed in most of the cultures irrespective of the concentration of growth regulator in the media, except in the absence of NAA. Maximum number of embryos were noticed in media containing 0.7 mg/l Kn in association with 0.2 mg/l NAA. Beyond 1.0 mg/l Kn, poor or no embryogenesis was observed. Also embryogenesis decreased when NAA level exceeded beyond 0.3 mg/l.

After 2–3 weeks of growth, mature embryos showed bipolar differentiation (Figure 1 *d*), subsequently developing into plantlets upon transferring to hormone-free medium. Eventhough root and shoot meristems were observed in somatic embryos, simultaneous development of root and shoot formation was infrequent. More often root formation occurred first which either resulted in induction of shoot apex or its noninduction. About 27% of the somatic embryos grew into normal plantlets on

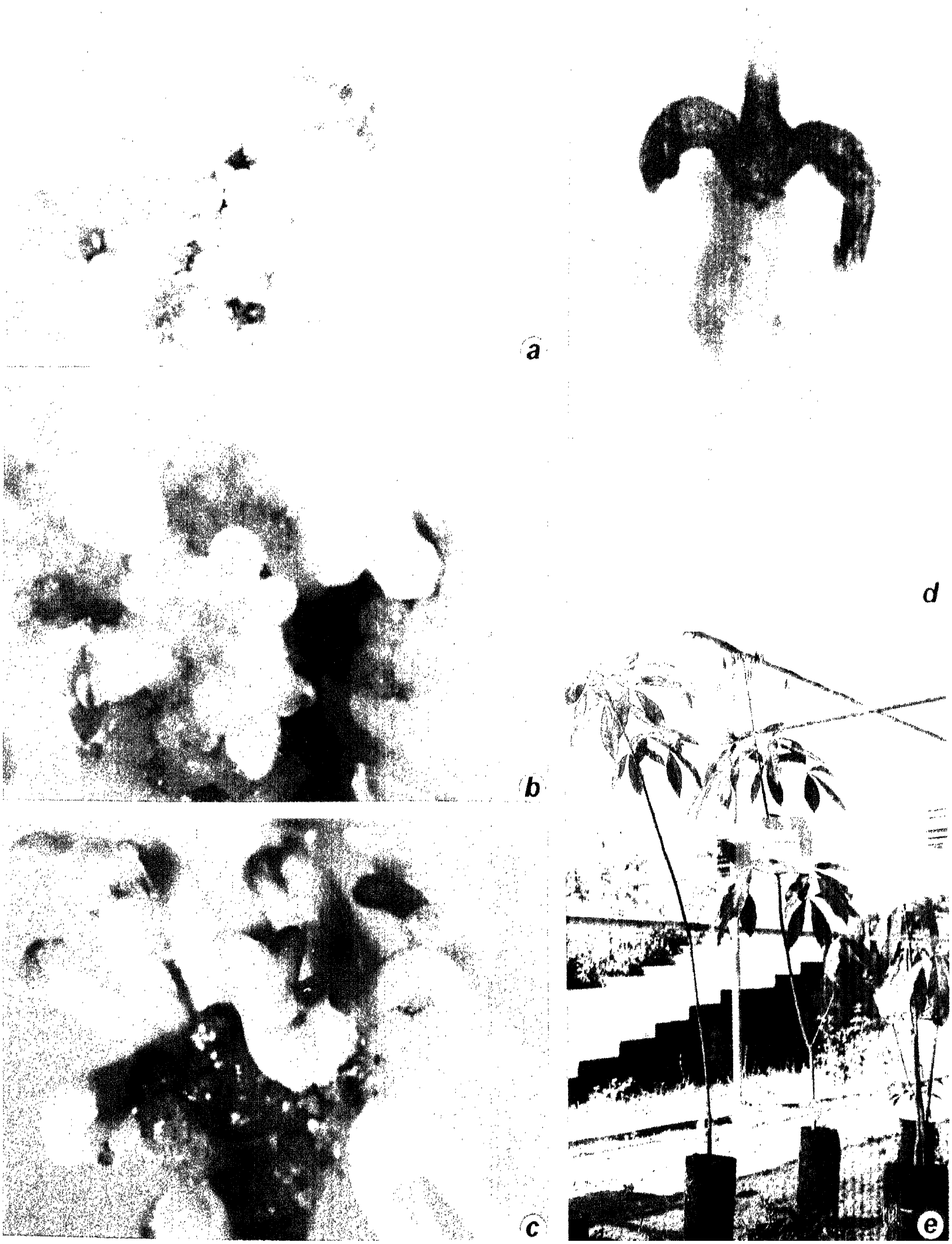

Figure 1. Somatic embryogenesis from immature anthers of *Hevea brasiliensis*: ***a***, Globular embryos emerged from ye[illegible] callus; ***b***, Whit[illegible] globular and heart-shaped embryos; ***c***, Green cotyledonary embryos; ***d***, Bipolar differentiation of embryos with r[illegible] and shoot poles ***e***, Embryo-derived plants growing in a greenhouse.

hormone-free medium. Cytological analysis of root tip cells from regenerated plantlets revealed only diploid cells. Plantlets that attained 2–3 cm length were planted in small polybags containing soil mix and were maintained in a greenhouse (Figure 1 *e*) prior to being transplanted in the field.

Table 3. Influence of NAA and Kn on the number of somatic embryos formed in *H. brasiliensis*

NAA (mg/l)	Kn (mg/l) 0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
0.1	4.67 ± 1.75	10.83 ± 1.33	15.33 ± 1.63	11.83 ± 1.72	5.67 ± 0.82	0.7 ± 0.82
0.2	10.0 ± 1.67	18.0 ± 2.37	23.83 ± 1.72	20.67 ± 2.58	10.3 ± 1.75	3.5 ± 2.74
0.3	2.83 ± 1.72	9.0 ± 1.79	14.17 ± 2.93	11.83 ± 1.72	4.67 ± 1.51	1.0 ± 0.89
0.4	0.50 ± 0.84	3.17 ± 1.47	6.0 ± 1.26	3.83 ± 1.47	1.33 ± 1.75	0.0 ± 0.0

Mean number of embryos (± SD) were recorded from pooled data after 4–5 months of culturing in embryo induction medium.

F = 10.92**; CD (0.05) = 1.95.

**indicates significant at $P < 0.01$.

A plant regeneration protocol via somatic embryogenesis was developed using immature anthers of *H. brasiliensis* (clone RRII 105). Modified MS medium supplemented with 2,4-D, NAA and Kn as plant growth regulators was found to be ideal for embryogenesis. This protocol could be applied to several Indian genotypes of *Hevea* for production of large-scale plants. The present regeneration system can also be used for developing transgenic plants either by *Agrobacterium*-mediated gene transfer or by particle bombardment with desirable genes.

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In vitro regeneration of a medicinal plant – *Houttuynia cordata* Thunb. from nodal explants

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***In vitro* regeneration of multiple shoots was achieved in nodal explant cultures of a medicinal plant *Houttuynia cordata* Thunb. (family Saururaceae) on Murashige and Skoog (MS) medium supplemented with 1 mg/l of N-6 Benzyladenine (BA). *In vitro* grown shoots were cultured for rooting on MS medium with 1 mg/l of indole acetic acid (IAA). The rooted plantlets were successfully established in soil.**

HOUTTUYNIA cordata Thunb. (family Saururaceae) is a wild perennial herb with creeping rootstocks and swollen nodes. The species exists in two chemotypes – the Japanese chemotype, which smells like orange and the Chinese chemotype which smells like raw fish and fresh coriander leaves[1]. The Chinese chemotype was used in this study. Mainly leaves and occasionally the whole plant of *H. cordata* are used as medicine. Leaves are used to treat cold, measles, dysentery, indigestion, and eye, urine and skin ailments[2,3]. The plant is used as a detoxicant, anti-inflammatory, antipyretic and diuretic agent in traditional medicinal practices of Assam and China[4]. Two pyridine alkaloids, three aporphine-related alkaloids (viz. cepharanone, cepharadione B and 7-chloro-6-demethyl cepharadione B) and aristolactans have been isolated from *H. cordata*[5]. It also yields essential oils[5].

Organized cultivation of *H. cordata* for extraction of medicinal compounds was reported from Vietnam[6]. In Assam, these plants are collected from natural population which is not abundant. *In vitro* propagation of this species could help in raising disease-free healthy clones

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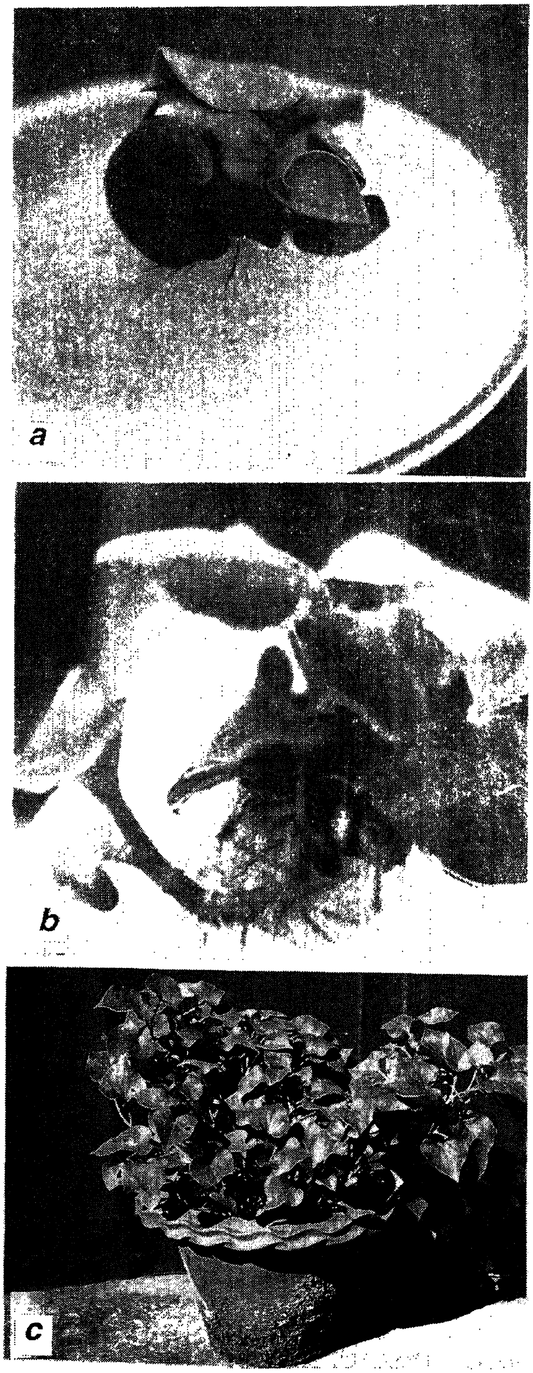

Figure 1. *a*, Initiation of rooting of *H. cordata* Thunb. in *in vitro* condition; *b*, *In vitro* growth of plantlet; *c*, Fully grown plant after 4 months of transfer.

in a large scale for extraction of pure alkaloids. This paper presents the results of *in vitro* regeneration of *H. cordata* from nodal explants.

Healthy shoots of *H. cordata* Thunb. were collected from the plants grown in the greenhouse and washed with tap water several times. Shoots were excised at the internodes and soaked in Tween 20 (20%) for 15 min with occasional stirring. The shoot segments were then washed several times with sterile distilled water (SDW) in a laminar airflow cabinet and then surface sterilized in 0.1% mercuric chloride solution for about 3 min followed by a thorough rinsing in SDW. These surface sterilized shoot segments were cut into 6–8 mm pieces. The shoot pieces which consisted of a single node containing a small portion of the internode on either side were used as explants.

The explants were cultured on MS medium[7] with 0.8% agar and 3% sugar, and with or without N-6 benzyladenine (BA), (0.2–1.0 mg/l) in 25 × 150 mm culture tubes. The pH of the medium was adjusted to 5.8 prior to autoclaving. The media were autoclaved at a pressure of 15 ib/inch^2 for 15 min. The cultures were maintained under 2000 lux light intensity provided by white fluorescent lamps for 16 h photoperiod at 25 ± 2°C. For each treatment 20 replicates were used. The growing explants were subcultured only once after 30 days. After 4 weeks of subculture, the growing shoots were cultured for rooting on MS medium (pH 5.8) containing indole acetic acid (IAA) (0.2–1.0 mg/l) keeping the incubation conditions same as before.

The nodal explants started growing after about one week of culture on MS medium with BA (0.75 and 1.0 mg/l), producing green shoot buds. Maximum number of shoots were obtained in the medium supplemented with 1.0 mg/l BA after 30 days of culture. The shoots were subcultured after 30 days. After 4 weeks of subculture, the shoots were cultured on MS medium supplemented with IAA. Adventitious roots developed from the base of the shoots after 21 days of culture and maximum number of roots developed in the presence of 1.0 mg/l IAA (Figure 1 *a*). The rooted plants were allowed to grow on the MS medium containing IAA up to 30 days and then transferred to liquid MS medium without hormone for 10 days (Figure 1 *b*). Thereafter, the plantlets were transferred into pots containing a sterilized mixture of garden soil and vermiculite (2:1). The plantlets were kept covered with a polythene bag for 10 days to check excessive transpiration. The plantlets were then successfully established in field condition and in big earthen pots (Figure 1 *c*). The acclimatized plantlets showed 95% survival.

The protocol standardized through this study demonstrates the possibility of developing an efficient *in vitro* propagation system for successful mass propagation of *H. cordata*.

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Carbonaceous megaremains from the Neoproterozoic Owk Shales Formation of the Kurnool Group, Andhra Pradesh, India

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An assemblage of carbonaceous compression and impressions recorded from the Owk Shales Formation (OSF) of the Kurnool Group include, Chuarid (*Chuaria circularis*), Tawuid (*Tawuia* sp.), Ellypsophysid, Moranid and Beltinid remains. The presence of *Chuaria-Tawuia* assemblage provides strong evidence of correlation with the assemblage of Rewa and Bhander groups of Vindhyan Supergroup and to some extent with the Halkal Formation of the Bhima Group. *Chuaria-Tawuia* assemblage is being considered as a potential biostratigraphic marker. In this communication we report varied groups of carbonaceous compression and impressions from the OSF of the Kurnool Group. On the basis of the present fossil assemblage, the OSF is considered to be of the Neoproterozoic age.

MEGASCOPIC remains are well recorded from the various 1.1–0.7 Ga-old sedimentary successions of the world[1,2]. In India, carbonaceous megascopic compression and impressions have previously been recorded from the Vindhyan succession of central India[3–9] and Bhima Basin[10–14] of south India. A sketchy report has also been made from the Kurnool Basin[15]. We report here a very well preserved and diversified megascopic assemblage from the Owk Shales Formation (OSF) of the Kurnool Group, and discuss its biostratigraphic significance in the light of other discoveries of carbonaceous megaremains.

The OSF is part of the Kurnool Group of the Cuddapah Supergroup exposed in the Kurnool District, Andhra Pradesh. It conformably overlies the Narji Limestone Formation and grades upwards into massive Panium Quartzite Formation[16–18] (Figure 1). OSF is a well-laminated, thin-bedded unit with shales, siltstones, and silty-clay stones. The shales are noncalcareous; light grey, buff, and khaki in colour. These shales intercalate with thin-bedded silty claystone in the lower part of the OSF and siltstone in the upper part of the OSF. The carbonaceous compression and impressions reported here are found in abundance on bedding planes at the shale-siltstone, and shale-claystone junctions of the OSF.

The first reference of the occurrence of carbonaceous remains (presently considered biogenic) was made by King[16] who reported, 'these are somewhat like cycloid shales of fish, but no organic structure has been recognized in them'. This observation suggests that although King noted these dark-spotted features on the bedding surface of the shale, he did not consider these as biogenic in origin. Later, Rajurkar[15], in a very brief communication, restudied these and compared the circular structures with *Fermoria* – a genus presently being considered as a junior synonym of the *Chuaria* Walcott. He did not however mention the other forms present in the OSF. We have noted several additional types of carbonaceous remains. The morphotype diversity of the carbonaceous remains, present in Precambrian sediments, has been divided into several groups[2]. On the same lines the present occurrence has been described as well.

The collection of fossil assemblage described here has been made from the eastern part of the hillock 1445, situated in the village Ankireddipalle (15°07′:78°03′) of the Kurnool district of Andhra Pradesh, south India (Figure 2). The exposed thickness of OSF at this place is about 15 m. While the lower 5 m part is dominated by claystone beds, the rest of the 10 m of succession is comprised of shale–siltstone alteration (Figure 3). The figures specimens are deposited in the repository of Birbal Sahni Institute of Palaeobotany, and catalogued under the BSIP Museum Numbers (38078–38082, slide number 12055), as cited in the individual figure captions. The present study of the fresh collection shows that the carbonaceous megafossil assemblage recorded from the OSF belongs to the following 5 groups.

Chuarid remains: The specimens are smooth-walled spheroids preserved as carbonaceous discs, ranging in size from 1–5 mm ($E = 3.11$: $N = 261$) (Figures 4 *c–f*). Occasionally a few forms show short, rounded extension at one place. Ford and Breed[19] placed the size range of the *Chuaria* from 0.5 to 5 mm. Vidal[20] from the study of assemblage in Visings Formation extended the lower extent of the size parameters to 0.09–0.2 mm and the upper limit up to 3 mm. Later, Vidal and Ford[21] included specimens as small as 70 μm in diameter in the category of *Chuaria circularis*. This indicates that there is still no unanimity about the lower size limit of *Chuaria*. However, the upper size limit is generally agreed to be 5 mm.

	Formation	Thickness^{36} (m)	Thickness^{37} (m)
Kurnool Group	Nandyal Shale	50–100	105–240
	Koilkuntla Limestone	15–50	0–90
	Panium Quartzite	10–35	0–60
	Owk Shales	10–15	0–18
	Narji Limestone	100–200	0–192
	Banganpalle Quartzite	10–50	0–9.6

…… Unconformity ……

Tadpatri Formation

Figure 1. The lithostratigraphy of the Kurnool Group[36,37].

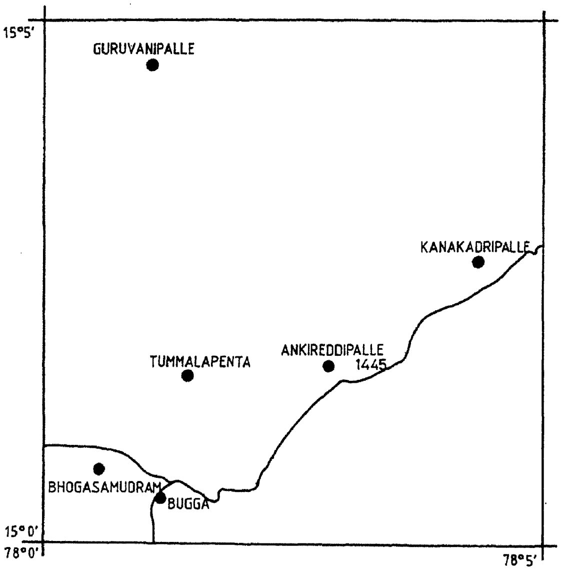

Figure 2. Locality map of the fossil-yielding area showing Ankireddipalle village from where the carbonaceous compressions have been recorded.

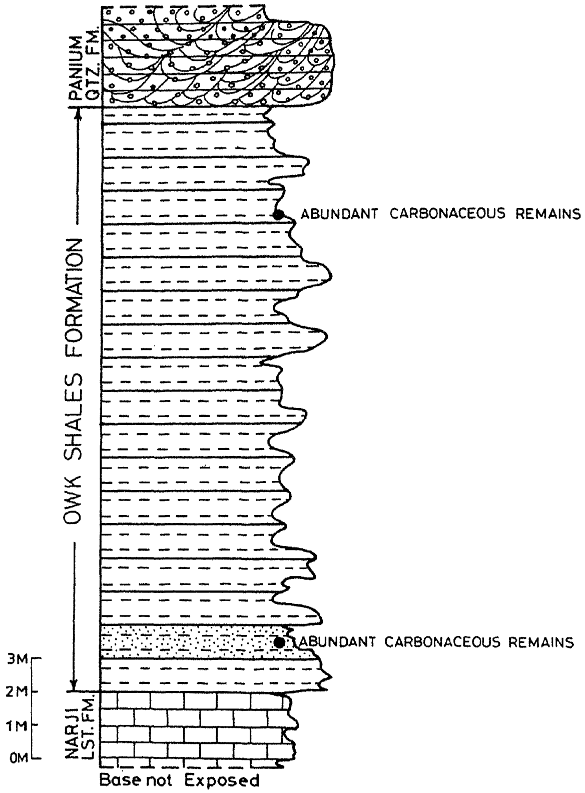

Figure 3. Lithostratigraphic succession of the strata exposed at Ankireddipalle village, Kurnool district, Andhra Pradesh, showing Narji Limestone Formation, Owk Shales Formation, and Panium Quartzite Formation, and indicating the levels of abundant occurrence of carbonaceous compression/impressions.

In India, the *Chuaria circularis* recorded from Suket Shales of the Semri Group, Vindhyan Supergroup, is in the size range of 0.5–1.25 mm (ref. 22) and the same noted from the Rohtas Limestone Formation ranges in size from 2–4 mm (ref. 14). The specimens recorded from Rewa Group are 1.0 to 3.7 mm with the average being 2.0 mm (ref. 8). The *Chuaria* specimens reported from the Bhander Group range from 0.2 to 5.1 mm, with a mean of 1.54 mm (ref. 9). Thus, the Vindhyan *Chuaria* specimens range in size from 0.5–5.0 mm. The Bhima specimens are 2–10 mm in diameter with a mean of 3 mm (ref. 14). Thus, the Indian records are in the range of 0.5–10 mm with a mean of ~5 mm.

Chuaria circularis is one of the carbonaceous remains from the Precambrian sediments which has been studied in great detail by several workers. These studies were undertaken to understand the nature and affinity of *Chuaria* with other groups. Although so far no conclusive proof is available about its affinities, it has been assigned to various groups. Based on the size parameters, *Chuaria* is categorized under acritarch, comparable to Leiospherids. Sun[23] considered this to belong to filamentous algae belonging to *Nostoc* which forms a ball. On the contrary, Gussow[24] considered this as a planktic form, while Steiner[25] considered this as micro- to macroscopic (? Chrocoocal organized) colonial prokaryote. But comparison with *Nostoc* does not hold good because *Nostoc* has a thin outer covering rather than the thick outer covering found in *Chuaria*, which may be original or taphonomic. For example, in artificially fossilized prokaryote, an organically impregnated envelope of prokaryotic colonies may simulate large unicells comparable to *Chuaria*. Thus, it is more likely that *Chuaria* is more akin to the large-sized prokaryote which has a thick outer coating.

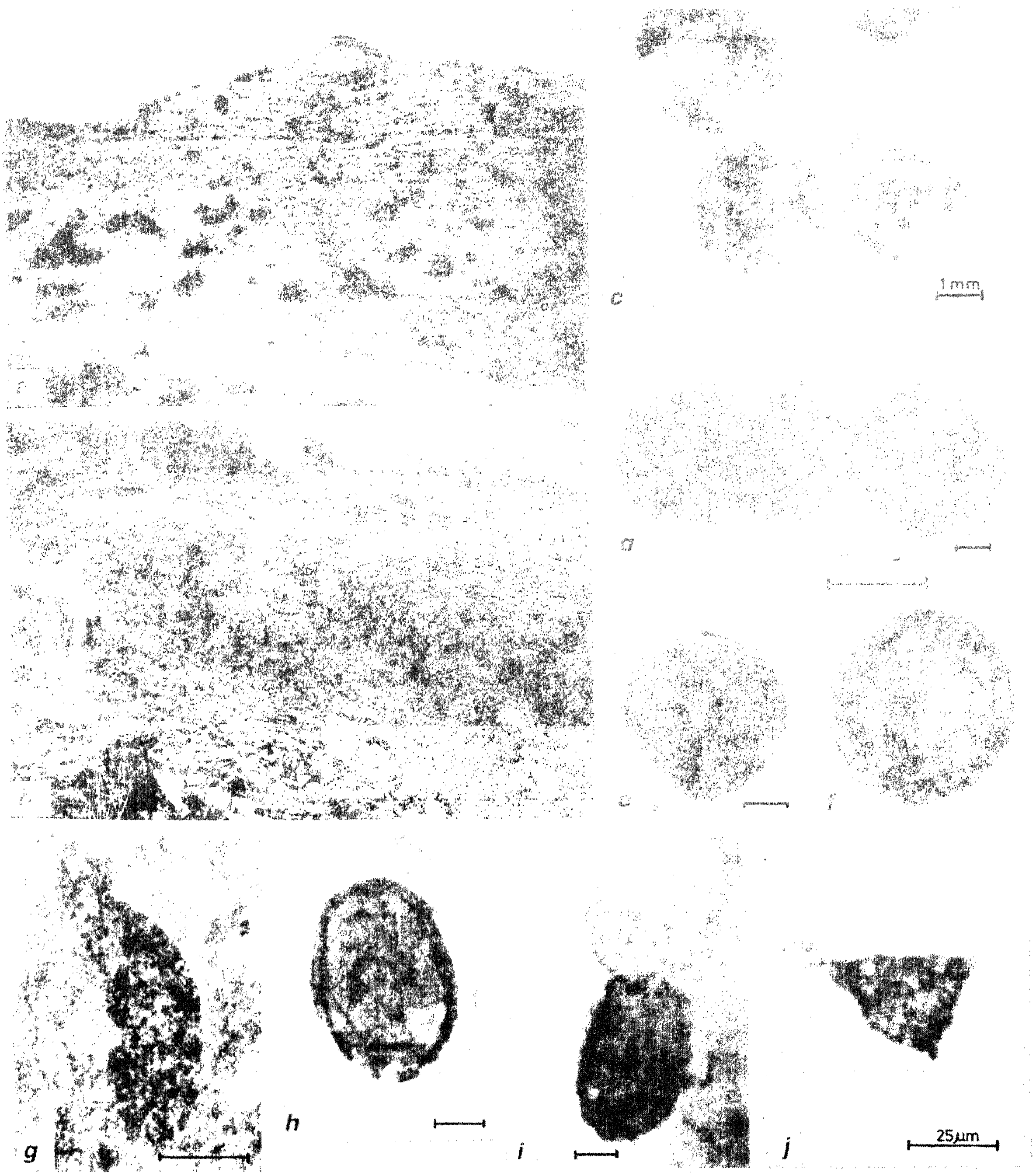

Figure 4. *a*, Section of Oak Shales Formation exposed at Ankireddipalle village; ***b***, close up of the strata yielding abundant carbonaceous megaremains; *c–f*, impressions and compressions of Chuarid remains (*Chuaria circularis*) showing solitary linear arrangement and ruptured outer covering of *Chuaria*. ***c***, Specimen no. BSIP-38078; ***d*** and ***e***, Specimen no. BSIP-38079; ***f***, Specimen no. BSIP-38080; ***g***, Tawuid remain, specimen no. BSIP-38081; ***h***, Moranid remain, specimen no. BSIP-38082; ***i***, Ellipsophysiod remain, specimen no. BSIP-38078; and *j*, Beltanid remain, BSIP slide no. 12055 England Finder Reading K 2/13.

Tawuid remains: These are short rectilinear, smooth tomaculate forms which are slightly bent or curved and are very few in number. The population density of *Tawuia* and tauwuid remains is very low in comparison to Chuarid remains in OSF. Their length ranges from 2 to 6 mm, and the width ranges from 1 to 4 mm (Figure 4 *g*). The specimens recorded from the Rewa Group have a length range between 3.3 mm and 5 mm, and a width range between 1.6 mm and 2.94 mm (ref. 8). In the Rewa Group, specimens show well-developed foldings and creases along the length of the form. *Tawuia* specimens have also been recorded from the Bhander Group. These specimens have a width of 0.8 to 1.6 mm with mean as 1.14 mm ($N = 8$), the maximum recorded length is 10.3 mm; cross wall and annulations have not been recorded in these specimens. Sharma and Shukla[13] and Maithy and Babu[14] recorded *Tawuia* from the Halkal Formation, Bhima Group, which are smooth, ribbon-like films, short and slender, straight or mostly twisted, parallel-sided with a size range of 15–30 mm in length, and 0.1 to 3 mm in width. It is common knowledge that *Chuaria* and *Tawuia* occur together, but the converse is not true. This feature has been noted in the OSF assemblage as well.

Hofmann (in Hofmann and Aitken[26]) considered the affinities of *Tawuia* as either algal (Phaeophyte?) or probably metazoan; however, later he opined that both *Chuaria* and *Tawuia* are eukaryotic algae[1]. Duan[27] considered *Chuaria* and *Tawuia* as advanced multicellular algae in the process of evolution. Sun[23] mentioned that *Chuaria* and *Tawuia* are closely associated because of their gross confirmation. This has been further supported by statistical data presented by some researchers[1,28].

The occurrence of *Tawuia* in the OSF assemblage is very characteristic of Neoproterozoic successions, and is helpful in establishing the age of OSF.

Ellypsophysid remains: The ellipsoidal and ovate to spatulate forms are included in this category, and considered intermediate between Chuarid and Tawuid remains. The specimens belonging to this category are miniature *Tawuia* type (Figure 4 *h*). Such specimens have been described as belonging to the genus: *Nephroformia*, *Pumilibaxa*, and possibly *Glossophyton*[26]. Specimens range in length from 2–5 mm and in width from 1–3 mm. These forms are perhaps related to longfengshanids type of carbonaceous organic remains attached to stalk, which at some point of time got detached and were therefore preserved[2,26]. Benthic macroalgae, *Longfengshania* and *Paralongfengshania*, occur in 0.9–0.85 Ga-old Qingbaikuouan Changlongshan Formation of the Yenshan Ranges[29]. This once again stresses the conjecture that *Chuaria-Tawuia* and ellypsophysid remains are characteristic of Neoproterozoic, the world over.

Moranid remains: These are large ellipsoidal to irregular, rounded impressions that do not show wrinkles, and are considered to lack or have a less-developed physically resistant wall. The microfossils occurring in the OSF range in size from 1–8 mm in length, and 2–4 mm in width (Figure 4 *i*). These forms appear to have affinity with the genus *Morania* and have been compared to the modern free-floating globoidal colonies of the cyanobacterium *Nostoc*[30,31].

Beltinid remains: This group includes angulate films of carbonised matter. The characteristic form of this group, *Beltina danai*, has been noted in the OSF assemblage. These films may represent either diverse remains of no special morphological shape or else just a structureless biogenic matter, or perhaps fragments of prokaryotic mats or colonies, or eukaryotic algae (Figure 4 *j*). The type material reported from Montana Belt Terrain, Greyson Shale Formation, Deep Creek Canyon, Montana, is fragmentary, angular carbonaceous compression as well as millimetric to centimetric size polygon, devoid of any ornamentation[32]. The specimens recorded from Halkal Formation of Andola Subgroup are typically similar to the type material[13,14]. The OSF specimens are small pieces of carbonaceous remains and similar to the type material.

The carbonaceous remains have been recorded from Palaeoproterozoic[33], Mesoproterozoic[34], and Neoproterozoic[1,2]. *Chuaria* has been even recorded from the Cambrian[35]. In Indian Precambrian basins, Vindhyan successions have been widely studied for both their micro- and megapalaeobiological remains. *Chuaria* and *Tawuia* have been recorded from the Semri[3,5–7], the Rewa[8], and the Bhander Groups[9] in central India. These occurrences indicate that carbonaceous remains were occurring widely during the Vindhyan Supergroups over a long period of time spanning from Semri to Bhander groups.

Similar carbonaceous remains are also known from the Bhima Basin[11–14]. Bhima assemblage is quite diversified in comparison to the other occurrences, but *Chuaria* and *Tawuia* are important components of this assemblage. A comparison of Vindhyan assemblage, comprising of *Chuaria* and *Tawuia*, with Bhima and Kurnool assemblages shows that these are akin in shape, size, and diversity. Besides, the host lithologies are markedly similar not only at these two areas but also in the OSF of Kurnool Basin. Though lithologically the host sediments are similar in all the three localities, the assemblage recorded from the Bhima Basin shows greater diversification in taxa than those from the OSF and Vindhyan successions. The occurrence of these forms in buff shales or silty shales or siltstone/claystone indicates that their preservation is facies-controlled. This similarity suggests the affinity of this assemblage for shale depositional realm, and points to the planktic nature of the organisms. Smooth forms like *Chuaria circularis* are considered to be free-floating planktic forms[24]. It is possible that these were brought in from the open sea and deposited in calm water bodies, such as lagoon/lake, where these shales were deposited and specimens got preserved.

Hofmann[1] proposed that the *Tawuia-Chuaria* assemblage zone can be considered as a potential chrono-biostratigraphic marker, and considered the period from 1.1–0.7 Ga as the Chuarian age. Although the OSF assemblage compares closely with the Mesoproterozoic Suket Shales assemblage, which predominantly comprises Chuarid and Grypanid remains, it shows closer similarity with the Rewa and Bhander assemblages which are Neoproterozoic in age. In the present assemblage, neither *Grypania spiralis* nor any other similar form has been noted. Hence on correlation, we presume that the Kurnool Formation is coeval to the Rewa and Bhander Groups of the Vindhyan Supergroup and the Halkal Formation of the Bhima Group. Thus, the present assemblage indicates a Neoproterozoic age for the OSF. Further search in the area may add to the diversity of palaeobiological remains of the Owk Shales Formation.

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Neotectonism – An offshore evidence from eastern continental shelf off Visakhapatnam

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A minor tremor measuring 4.5 on the Richter scale occurred around 4.58 p.m. on 18 December 1995, with its epicentre located in the Bay of Bengal, nearly 30 km east of Vizianagaram on the Andhra Pradesh coast. The location of the epicentre is around 18°N and 83°42'E. It is significant that the epicentre falls in the innershelf off Vizianagaram, where a suite of rocks (Santapalle Rocks) outcrop at a water depth of around 30 m.

Bathymetry and magnetic data were collected over this region along closely spaced, coast parallel profiles covering the shelf regions. Observed magnetic anomalies are of short wavelength and high amplitude of the order of 600 to 700 nT. Two-dimensional modelling of these anomalies with conventional as

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*For correspondence.

well as inversion methods indicates a severely faulted and folded basement of the order of 1 to 6 km. Three closely spaced river channels (Nagavali, Vamsadhara and Nellimarla) trending NW–SE are associated with the faulted and folded basement. Faulting associated with the Nellimarla river channel extending into the offshore zone may be the possible cause of the tremor.

Strong magnetic anomalies, complex basement structure, exposed rock outcrops in the innershelf (20 m) in the vicinity of the epicentre of Vizianagaram earth tremor provide evidence of Neo-tectonic activity in this region. The epicentral region falls in a shallow marine environment ideal for generating a geophysical database for stable continental region earthquakes.

THE plate tectonics theory assumes that a strong lithosphere overlies the weaker asthenosphere and lithospheric plates are undeformed except at their boundaries. Some observations that apparently violate these assumptions are recorded from the Central Indian Ocean Basin (CIOB) like intraplate seismicity, anomalous heat flow, deformed oceanic crust and overlying sediments which stand as the example of intraplate deformation of the oceanic lithosphere resulting from compressional forces in the equatorial Indian Ocean.

Southern peninsular India, bounded by passive margins, is so far considered stable being an intraplate zone. But this view is belied by the recent occurrences of earthquakes in Latur (Maharashtra) and Jabalpur (Madhya Pradesh).

Geophysical, geological and geomorphological studies of south India revealed neotectonic activity represented by:

(1) A basement upwarp along 13°N latitude acting as a water divide separating north flowing rivers from south flowing rivers[1].

(2) A lineament close to 13°N latitude identified as a new seismogenetic belt[2].

(3) A significant change in magnetic anomaly pattern off Chennai at 13°N latitude interpreted as a major structural discontinuity[3].

(4) Well-documented regional lineaments on Quaternary and recent sediments[4], deformation of south Indian shield into a series of E–W arches and depression due to stress-related activity[5] from remote sensing studies and occurrence of several faults in the surface and sub-surface sediments from high resolution shallow seismic data off Bhimunipatnam and Pudimadaka[6]. The present study deals with magnetic data in the offshore zone off Visakhapatnam–Kalingapatnam.

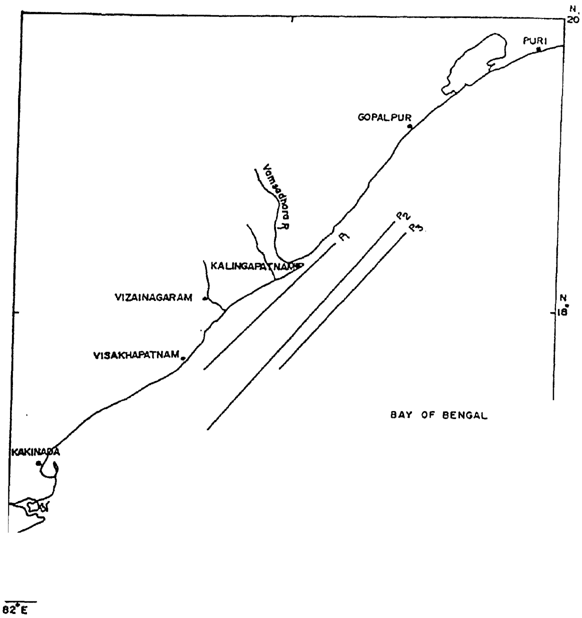

Figure 1. Location map showing 3 parallel profiles between Visakhapatnam and Kalingapatnam.

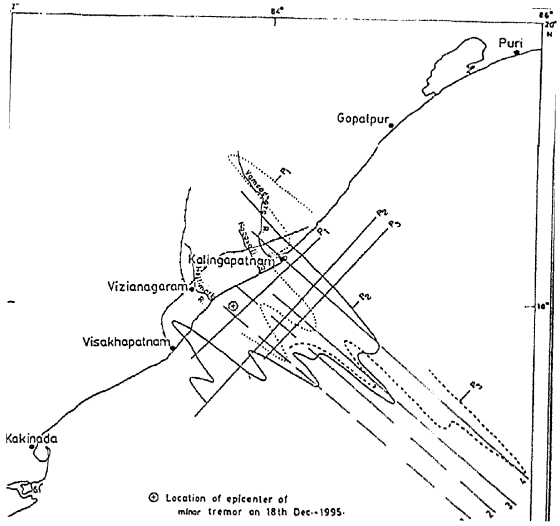

Figure 2. Magnetic anomalies along 3 parallel profiles.

Total field magnetic data used in the present study were collected during the 245th cruise of *RV Gaveshani* along three coast parallel profiles (Figure 1) between 30 and 100 m water depth over innershelf off Visakhapatnam. Each profile is 15 to 30 km long. Barringer proton precession magnetometer was used with a sensor towed nearly 150 m behind the vessel and the data were

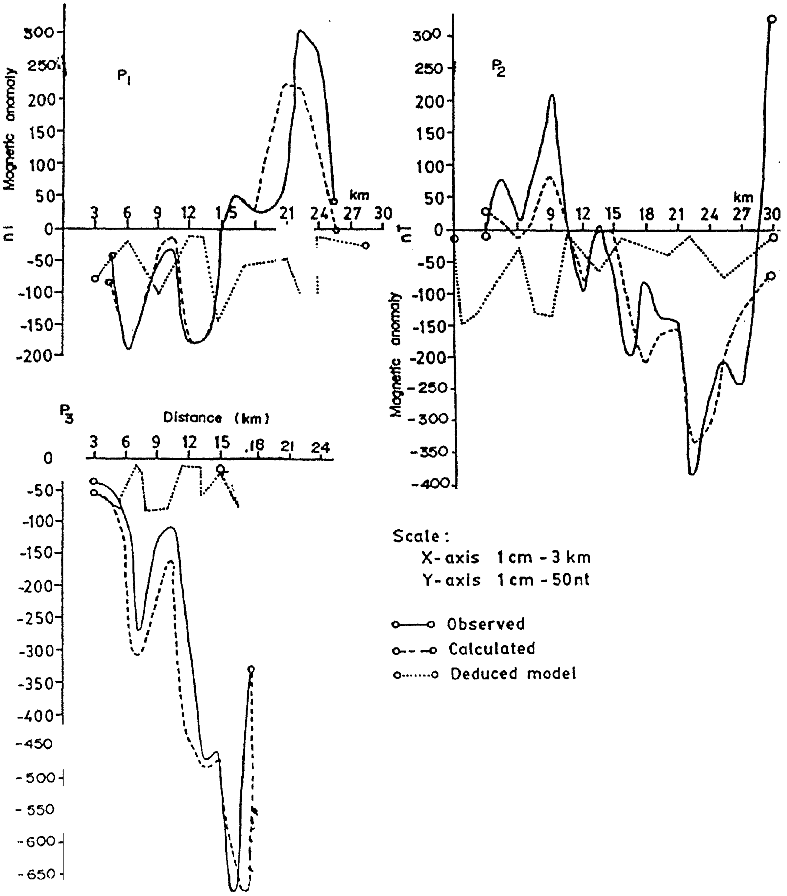

Figure 3. Two-dimensional models of 3 anomalies.

collected at 1 min polarization interval. Observed data were corrected applying IGRF corrections.

Magnetic anomalies are plotted along 3 profiles P1, P2 and P3 between Visakhapatnam and Kalingapatnam (Figure 2). Profile P1 close to the shore is associated with negative anomalies of the order of 200 nT at a water depth of 30 m. Profile P2 and P3 are characterized by short wavelength and high amplitude negative anomalies of 400 to 650 nT. Four major lineations (1, 2, 3 and 4) trending NW–SE are inferred from the anomalies (Figure 2). Two-dimensional modelling[7] of magnetic anomalies indicate a severely undulating basement with depth ranges between 200 m and 10 km. The basement topography inferred along profiles P1 and P2 is highly disturbed (Figure 4). The three trends 1, 3 and 4 appear to be the offshore continuation of 3 river channels inland. Geological studies of the inland region between Visakhapatnam and Kalingapatnam reveal that it is a relatively disturbed area, associated with severe folding and faulting in the shallow basement[8]. The Nellimarla river fault is a major one extending into offshore regions and spatially correlated to trend 1 inferred from our studies and to this particular trend only, the epicentre of the recent earth tremor (A in Figure 4) lies at nearly 20 m water depth about 30 km offshore from Vizianagaram in the Bay of Bengal. Two other river channels, like Nagavali and Vamsadhara, cutting across the coast are likely to extend offshore into the Bay of Bengal near Kalingapatnam which may be related to trends 3 and 4 inferred from geophysical data.

High resolution shallow seismic data along parallel profile off Bhimunipatnam indicate steep subsurface faulting (F in Figure 5) about 35 m below the seabed. Uniform and parallel bedding is observed in the left segment of the subsurface unit while another segment is inclined towards the fault plane suggesting deformation (Figure 5). In view of the several deformations noticed in the sedimentary units above and below the seabed at places off Visakhapatnam in the eastern continental

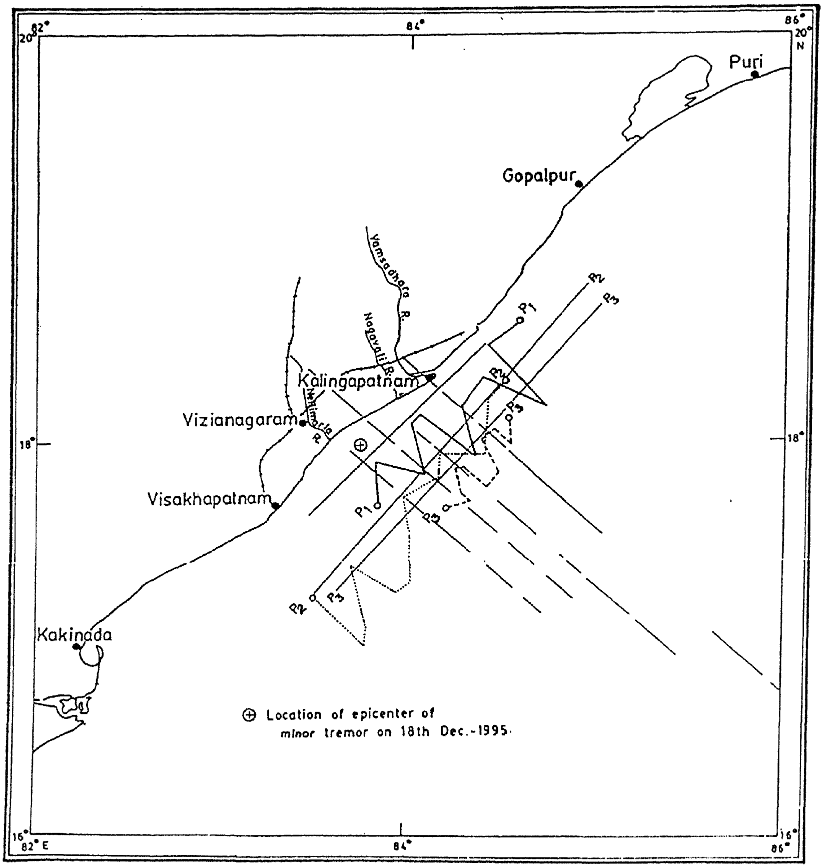

Figure 4. Magnetic basement inferred from model studies.

shelf, there is a possibility of recent tectonic movements in this region. Nearly 158 earthquakes were recorded within 30 km off Visakhapatnam during 1974 to 1976. Epicentres of 44 of these shocks are shallow with their foci between 0 and 30 km (ref. 9).

In the light of these observations and geophysical data interpretation and available geomorphological information, it may prove fruitful to establish the link between onland and offshore tectonic lineaments which would help one understand the factors responsible for the recent tectonic activity in the southern part of peninsular India.

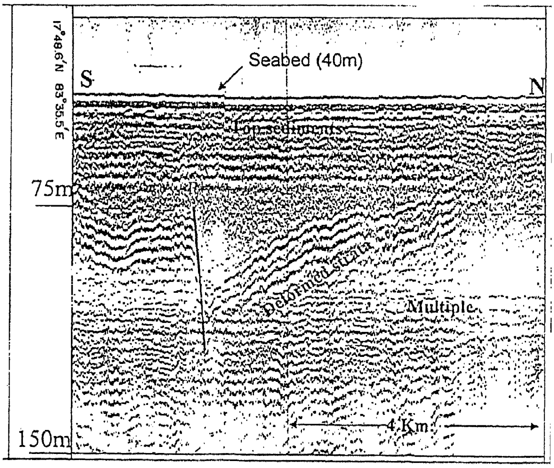

Figure 5. Shallow seismic record showing sub-bottom fault off Bhimunipatnam.

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In situ maturation of sediments within the weathering profiles: An evidence from REE behaviour during weathering of Delhi quartzites

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Orthoquartzites of Delhi Supergroup in Delhi region have low abundance of REE. There is a two-fold enrichment of REE in moderately weathered zones on the quartzites accompanied by increase in the amount of kaolinite. The REE patterns however are nearly identical to those of the unweathered core quartzite. In the strongly weathered outer zones both kaolinite and REE abundance decrease somewhat relative to the lower weak to moderately weathered zones. The weathering processes here involved are the formation of kaolinite possibly by the breakdown of a few grains of mica and the oxidation of pyrites present in the quartzite. During this process, the REE have been mobilized quantitatively by sulfate-bearing solutions without any fractionation. In the process the outermost zones have been made friable with lowered REE abundance. It is possible, that REE and Al depleted top friable zones may have been physically eroded away. Thus, although the REE are mobile in upper zones during weathering processes, they could be quantitatively retained in the lower weathering zones due to clay forming processes resulting in the production of silica-rich, REE depleted mature quartzite by stripping off the uppermost friable sediments of the rinds.

ALTHOUGH there have been many studies on the weathering of igneous rocks, there are few data concerning weathering of quartzite[1,2]. Quartz or its polymorphs form the end member oxides to the rock forming silicate minerals and this resistant mineral is a rate-limiting component in the weathering of rocks[3]. A study of weathering of quartzite which is composed mainly of quartz (~ 99%) will help us to understand between the weathering of this resistant mineral. REE geochemistry on fresh and weathered quartzite has been used to infer the mechanism and nature of solutions responsible for chemical weathering of quartzite. There have been studies showing that the rate of chemical weathering and erosion of weathering profiles are important in controlling the chemistry of sediments derived from them[4,5]. The sand derived from mature weathering profiles have less provenance information than the mud which contain better information[5]. Separation of sand and mud grade detritus by fluvial processes after the erosion of extremely weathered profiles has been suggested for the origin of first cycle quartz arenites[6,7]. Our present study provides a mechanism for the formation of supermature quartzite, with very low REE abundance, directly from the weathering arenaceous sediments without going through a long transportation and thereby differentiation into sand and mud grade sediments.

Middle to late Proterozoic metamorphozed quartzite of the Delhi System is exposed as a series of subparallel ridges in the Delhi and adjacent Haryana regions (Figure 1). The topographic depressions on the ridges have accumulated aeolian sediments transferred from the adjacent Thar desert of Rajasthan by the prevailing winds[8]. The quartzites have been intruded by pegmatite and quartz veins. The rocks have undergone extensive weathering in and around fracture zones through infiltration of meteoric water and dust. Occasionally massive quartzite bodies on top of the ridges (maximum elevation around 100 m relative to the local elevation) show development of a half to one meter thick, colour and texture zoned weathering rind (Figure 2). The region is semi arid with an annual rainfall of about 75 cm. We studied the chemical and mineralogical compositions of

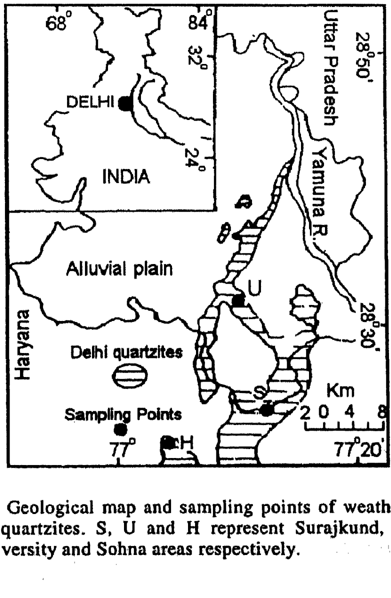

Figure 1. Geological map and sampling points of weathering rinds on Delhi quartzites. S, U and H represent Surajkund, Jawaharlal Nehru University and Sohna areas respectively.

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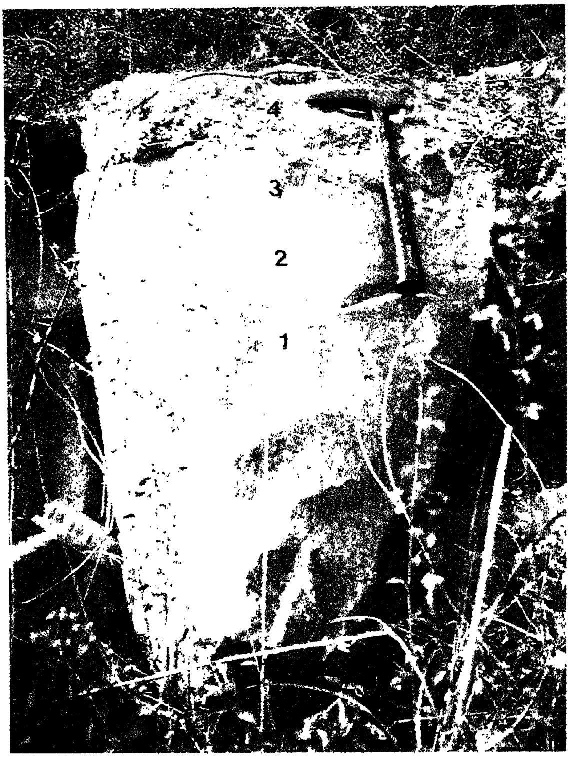

Figure 2. A typical weathering profile on Delhi quartzite showing unweathered core (1), compact pinkish-white zone (2), moderately weathered red zone (3) and friable red zone (4).

weathering rinds from three different locations, about 15 km apart (Figure 1). The samples were processed and analysed for their mineralogy and geochemistry (major, trace and rare earth elements)[9].

To quantify the extent of weathering, Chemical Index of Alteration (CIA) was calculated using molar proportion of the oxides[10]. This index is defined as:

$$\text{CIA} = (\text{Al}_2\text{O}_3/\text{Al}_2\text{O}_3 + \text{CaO}^* + \text{Na}_2\text{O} + \text{K}_2\text{O}) \times 100;$$

where CaO* represents the calcium in silicate fraction only. In the absence of CO_2 data, correction for CaO in carbonate mineral is difficult. Therefore, in the samples where molecular proportion of CaO (after correction for apatite) is greater than molecular proportion of Na_2O, CaO is assumed to be equal to Na_2O (ref. 11).

It has been found that the quartzite weathers to a white bleached zone immediately adjacent to unweathered core, which then becomes somewhat pinkish to red zone outward in the weathering rind system (Table 1). The outer rinds gradually become friable due to leaching of minor minerals in quartzite such as pyrite, muscovite and calcite occurring along the boundaries of quartz grains. The rugged top surface may help in holding dust materials to support growth of the microorganisms and plants which after decay in oxidizing environment provide carbonic and other organic acids. The red colour results from the oxidation of Fe^{2+} to Fe^{3+} in the outer zones.

Rain water percolates through the top porous zones to the less porous advancing weathering front. The water flowing down oxidizes trace amounts of pyrite present in the quartzite. This can be easily seen after a rain wash on freshly opened quartzites as red patches left behind by dissolving pyrites. This process must have made the percolating solution acidic and sulfate-rich, which can then easily attack the lesser amounts of primary minerals such as muscovite and feldspar and carbonate grains present in the quartzite. Although these minerals do not appear in the X-ray diffractogram they are seen in the thin sections in trace amounts (< 1%). Ferrous iron of dissolved pyrites present in the solution could also attack the quartz grains of quartzite to make them friable[12].

In the weathered rinds kaolinite appears in the white zones in all the three cases and increases to its maximum level in the outer pink zone and then reduces in the outer friable zones (Table 1). The reduced amounts of kaolinite in the outer zones may be due to the illuviation process, but it is noted here that the Al content is always highest in outer zones which also have the highest CIA values. This indicates that a free Al phase such as diaspore may contribute to the highest Al and CIA values. It is likely that aeolian contribution has depressed the CIA values so that it is not 100 except for the H3 sample, which is compact and seems to be devoid of aeolian dust on its plane surface.

The quartzites in all the cases have nearly 99% silica. The other elements in measurable concentration are Al, Fe, and Ca. They are all characterized by very low abundance of REE. Table 2 gives the REE distribution within the different samples of the three profiles. REE patterns of these three quartzite samples are very similar (Figure 3 *a–c*). They have strong but slightly variable negative Eu anomalies. Although the low REE abundance is consistent with the extremely high silica content of these quartzites, the mechanism by which these are linked has not been understood. However, LREE enriched patterns of the quartzite, including the negative Eu anomaly are similar to those reported for quartzite with much higher REE abundance and lower silica content. In all cases the concentrations of REE in the lower, moderately weathered rinds, have gone up by a factor of two; the patterns, however, including the Eu anomaly remain essentially unchanged excepting in the topmost friable zones where the HREE become less fractionated (Figure 3 *a–c*). Among the other elements in the rinds only aluminium consistently shows an increase. The observed correlation between REE abundance and Al, and the abundance of kaolinite in the rinds, suggests that Al and REE must have been mobilized and precipitated down in moderately weathered zones of the profile by percolating solutions. During this weathering process there is no fractionation of REE because the patterns remained identical to that of unweathered quartzite. The

Table 1. Nature of weathering rinds, kaolinite content and extent of weathering

Sample	Nature of the rinds	Kaolinite (%)	CIA	Al_2O_3(%)
S4	Red friable sand	1.0	87.0	1.9
S3	Moderately weathered pink zone	2.0	80.7	0.66
S2	Compact bleached whitish zone	0.8	76.0	0.42
S1	Unweathered core	0.0	67.6	0.39
U4	Red friable sand	1.6	93.5	1.26
U3	Moderately weathered red zone	2.8	90.2	0.78
U2	Compact pinkish white zone	1.3	88.4	0.57
U1	Unweathered core	0.0	73.5	0.42
H3	Red compact weathered zone	1.8	100	0.73
H2	Compact bleached zone	2.8	97.3	0.67
H1	Unweathered core	0.0	64.2	0.60

Table 2. Rare earth element concentrations of different rinds of different profiles in ppm

	U1	U2	U3	U4	H1	H2	H3	S1	S2	S3	S4
Ce	6.34	12.13	8.75	12.87	13.42	10.10	18.71	6.70	7.32	13.68	11.89
Nd	2.63	5.04	2.10	4.50	5.70	4.26	8.42	2.68	3.62	6.64	4.92
Sm	0.47	1.00	0.41	0.81	1.02	0.83	1.68	0.56	0.77	1.48	0.98
Eu	0.06	0.17	0.06	0.12	0.19	0.17	0.36	0.08	0.13	0.28	0.17
Gd	0.46	0.88	0.50	0.73	0.98	0.81	1.53	0.50	0.72	1.28	0.83
Dy	0.40	0.74	0.58	0.79	0.82	0.86	1.20	0.45	0.67	1.02	0.74
Yb	0.23	0.39	0.40	0.51	0.46	0.55	0.57	0.24	0.36	0.45	0.43
Ce_N/Yb_N	7.05	7.96	5.60	6.46	7.46	4.70	8.40	7.14	5.20	7.78	7.07
$Ce_N/Sm_N/Ce_N/Sm_N$	3.19	2.86	5.04	3.75	3.11	2.87	2.63	2.83	2.25	2.18	2.87
Gd_N/Yb_N	1.61	1.81	1.00	1.15	1.71	1.19	2.16	1.67	1.61	2.28	1.55
Eu/Eu*	0.39	0.55	0.41	0.47	0.58	0.63	0.69	0.47	0.53	0.61	0.57

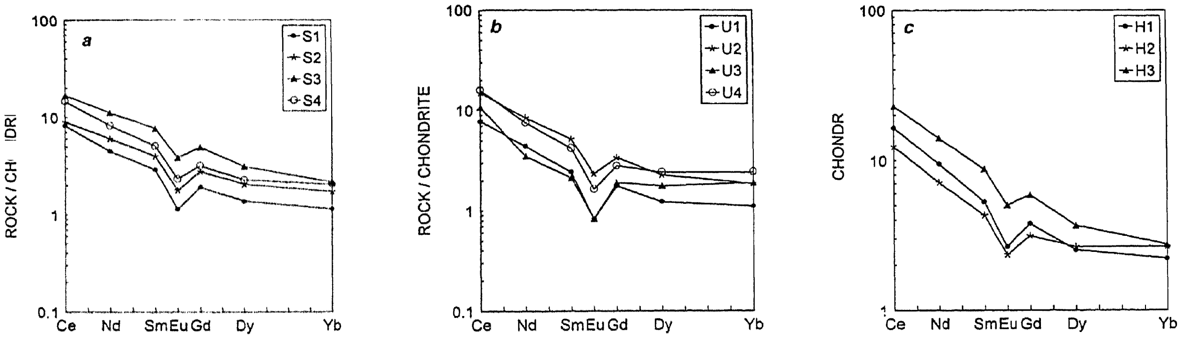

Figure 3 *a–c*. Chondrite normalized patterns of weathering profiles of *a*, Surajkund; *b*, J. N. U.; and *c*, Sohna.

nearly two-fold increase in the concentration of the REE in the lower moderately weathered zones is likely to be the result of addition of REE from the top of the weathered zones as adsorbed species or colloidal illuviated clays. However, we have not encountered the REE depleted zones in the outermost part. This implies that the zone from which REE and Al were removed was probably eroded away. It appears that during the weathering of quartzite there is a geochemical fractionation by which Al and REE may have been selectively retained by the process of clay formation or illuviation and the friable top surface zone developed must have become quite susceptible for physical erosion. We suggest that this process provides one mechanism by which high silica quartzites with very small concentration of REE could form in geological times.

The similarity of REE patterns in the compact zones of weathering rinds to that of the quartzites in the core is very striking. All the rare earths including Eu seem to have been quantitatively mobilized by the weathering solutions. This is possibly due to the formation of acidic sulfate complexes released by the oxidation of pyrite grains present in the quartzite. It has been reported that sulfate-bearing solutions could effectively mobilize the REE without fractionating them[13]. In the uppermost friable zones, a small flattening of HREE pattern has been observed. This could be due to the possible presence of carbonate complexes released by weathering of organic materials in the presence of meteoric water and due to the greater solubility of HREE in carbonate complexes[14].

From the geochemical characteristics of the weathering rinds of the Delhi quartzites we infer that, (i) rare earth elements can be mobilized in upper zones and retained in the lower moderately weathered zones during clay forming processes; (ii) presence of acid and sulfate ions in the weathering solutions can mobilize the REE without any fractionation; (iii) similar weathering processes accompanied by sedimentary redistribution processes could result in the formation of silica-rich quartzite with low REE abundance from their protoliths; and (iv) longer time span for the weathering and redistribution within the profile could have been an important process for the *in situ* maturation and production of silica-rich sediments, (e.g. mature quartzites) under stable cratonic situations.

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Petrogenesis of the protolith for the Tirodi gneiss by A-type granite magmatism: The geochemical evidence

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In the Central Indian region, the Tirodi gneisses occur intimately associated with the Sausar Group metasediments. The protoliths for these gneisses might have originated by rift-related intracontinental felsic A-type (anorogenic) magmatism. The geochemical signatures in them like high Zr + Nb + Y + Ce, Ga/Al, Zr/Ni, Rb/Sr and Y/Sc, are quite similar to the A-type granite characteristics and point to the derivation of the protoliths by the melting of lower crustal dehydrated assemblages at high temperatures attained as a result of possible ponding of basaltic magma/magma underplating. The occurrence of mafic rocks related to subduction zone magmatism and back-arc environment in the vicinity of these gneisses in the Central Indian region attest to such an origin for the protoliths of the Tirodi gneisses.

IN the Central Indian region, the Tirodi gneiss is a major lithological unit (Figure 1). These quartzo–feldspathic granitic gneisses are intimately associated with the metasediments of the Sausar Group. The basement–cover relationships of the granitic gneisses and the associated metasediments are obscured by the extensive migmatization at several places especially at the peripheries. There exist two schools of thought regarding the mutual relationships of the Tirodi gneisses and the metasediments of the Sausar Group. One school subscribes to the theory that the Tirodi gneisses constitute the basement on which the sediments of the Sausar Group have been deposited, while the other group of workers are of the opinion that the protoliths of the Tirodi gneisses intruded into the sediments of the Sausar Group[1–3]. Rb–Sr isotopic studies[4] could not help much in resolving this issue. In the absence of reliable and quality trace and rare earth element (REE) data, the limited studies so far on the Tirodi gneisses, could not focus on the petrogenetic aspects of the protoliths of these gneisses.

In this study, an attempt is made to throw some light on the nature of the magmatism that led to the formation of the protoliths of the Tirodi gneisses, based on a comprehensive new set of major and trace element (including REE) data of 20 representative samples of the Tirodi gneisses. Further the possible petrogenesis of the protoliths is evaluated.

Tirodi gneiss is a part of the Central Indian gneissic complex (Figure 1) and is exposed to the north of the supposed Central Indian suture (CIS). The samples studied are mainly from areas surrounding the mining

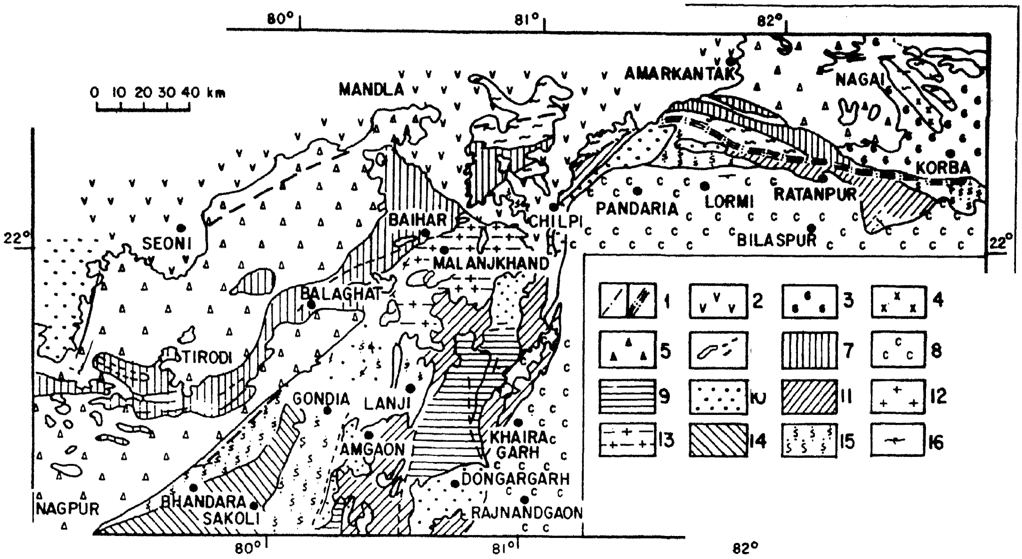

Figure 1. Geological map of the Central Indian region, showing the location of the Tirodi gneiss. 1, CIS/Mylonite zone; 2, Deccan basalt and Lameta formation; 3, Gondwana group; 4, Granites; 5, Tirodi gneiss; 6, Granulites; 7, Sausar metasediments; 8, Chattisgarh group; 9, Khairagarh group; 10, Chilpi group; 11, Nandagaon group; 12, Dongargarh granitoid; 13. Malanjkhand granitoid; 14, Sakoli group; 15, Amgaon gneisses; 16, Attitude of bedding.

Table 1. Representative major and trace element compositions of the Tirodi gneiss*

Wt%	MC52	MC53	MC67	MC76	MC77	MC80	MC97	MC125
SiO_2	59.07	69.05	72.47	75.49	62.95	68.20	63.66	75.69
Al_2O_3	16.18	15.28	14.25	13.55	15.05	14.99	16.56	13.83
TiO_2	1.62	1.08	0.64	0.17	1.02	0.85	0.70	0.03
CaO	2.63	1.63	1.91	0.65	0.69	2.26	1.24	0.88
MgO	2.47	0.83	0.67	0.03	5.23	1.83	0.72	0.03
$Fe_2O_3{}^T$	9.43	3.23	2.95	1.04	8.03	4.94	6.31	0.98
Na_2O	3.07	2.46	3.06	2.79	1.79	2.78	3.31	3.57
K_2O	5.04	6.85	4.96	6.58	6.00	4.62	8.14	5.21
MnO	0.06	0.04	0.03	0.02	0.05	0.06	0.14	0.05
P_2O_5	0.28	0.19	0.12	0.01	0.07	0.30	0.07	0.01
Total	99.85	100.64	101.06	100.33	100.88	100.83	100.84	100.28
A/CNK	1.06	1.03	1.08	1.06	1.40	1.09	1.00	1.05
(ppm)								
Sc	18	4	13	6	15	10	12	9
V	8	7	3	1	52	9	23	14
Cr	8	5	4	5	51	12	14	11
Ni	3	3	4	5	26	9	7	16
Cu	3	3	1	1	20	2	2	1
Ga	71	18	33	24	26	31	67	14
Rb	127	129	226	295	277	218	177	182
Sr	153	250	59	34	34	202	22	72
Y	104	9	84	55	10	26	78	49
Zr	877	17	756	330	127	308	385	130
Nb	35	17	13	9	16	15	281	1
Cs	1	1	2	3	8	5	1	1
Ba	893	1713	260	112	429	503	83	265
Hf	20	1	17	10	4	7	3	7
Ta	2	1	1	1	3	2	11	1
Th	100	1	48	63	23	27	3	8
U	5	1	7	7	3	1	1	1

*Complete set of data can be obtained from the authors.

Table 2. Representative rare earth element compositions of the Tirodi gneiss

(ppm)	MC52	MC53	MC67	MC76	MC77	MC80	MC97	MC125
La	264.54	39.81	92.00	45.16	40.82	58.12	96.75	5.21
Ce	388.18	58.21	149.04	98.81	72.92	119.90	155.05	22.55
Pr	45.39	7.66	18.02	11.06	8.89	17.47	23.57	3.26
Nd	122.03	20.79	50.15	30.32	30.58	32.79	83.15	9.34
Sm	21.83	3.94	9.18	6.44	6.84	5.67	15.38	3.05
Eu	1.79	2.16	0.54	0.37	0.97	0.76	0.49	0.59
Gd	16.80	3.51	7.17	4.70	4.26	5.03	10.55	2.66
Tb	2.99	0.37	1.31	0.86	0.83	0.94	1.98	0.68
Dy	18.91	1.69	8.63	5.59	2.75	6.47	12.18	5.13
Ho	2.50	0.31	1.87	1.29	0.37	0.57	1.86	1.07
Er	6.62	0.91	4.22	3.64	1.23	1.65	5.68	3.05
Tm	0.67	0.15	0.66	0.46	0.17	0.25	0.62	0.46
Yb	4.25	0.61	4.51	4.08	0.51	1.87	4.25	3.23
Lu	0.57	0.05	0.56	0.61	0.10	0.12	0.65	0.45
ΣREE	897.07	140.17	347.86	213.39	171.24	251.61	412.16	60.73
Ratio								
La_N/Yb_N	46.50	46.90	14.60	8.00	57.30	22.30	10.10	2.00
Ce_N/Yb_N	25.36	26.53	9.19	6.70	39.67	17.82	10.12	1.94
La_N/Sm_N	8.12	6.52	6.47	4.55	3.82	6.62	4.04	1.96
Gd_N/Yb_N	3.27	4.77	1.32	0.95	6.91	2.22	2.05	0.68
Eu/Eu*	0.28	1.78	1.20	0.21	0.54	0.44	0.12	0.63

town of Tirodi. These granitic gneisses are divided into grey and pink granitic gneisses which grade imperceptibly into each other. Pink gneisses cut across the grey gneisses and both are traversed by aplites and pegmatites. These gneisses show E–W trending foliation defined by parallelism of the micas and elongate feldspar and quartz grains. Migmatites of pink and grey colour are banded in appearance and are always associated with granitic gneisses but are less frequent. Ptygmatic folds of quartzo–feldspathic veins are common.

The essential mineral assemblages in these gneisses are quartz, microcline–microperthite and plagioclase. Deformation is not significant and no deformation textures are noticed. Antiperthite, chess-board albite and albite rims around plagioclase at the contact of k-feldspar are present. The plagioclase in these rocks varies from albite to andesine. The twin laws observed in plagioclase suggest magmatic origin for the protoliths of these gneisses while those of migmatites favour a metamorphic origin in the upper amphibolite facies. K-feldspars show ex-solution perthites indicating the high temperature condition of formation. Presence of antiperthites also suggests high grade metamorphic or anatectic conditions. Both biotite and muscovite form the micas. The accessories include zircon, apatite, sphene, tourmaline and magnetite.

Twenty representative samples of the Tirodi gneiss were analysed for major, trace and rare earth element compositions. Selected analyses are given in Tables 1 and 2. These gneisses are characterized by a wide range of compositions with SiO_2 ranging from 59.07% to 75.69 wt% (Av. 70.59%); with moderate to high Al_2O_3 (13.37 to 16.56%; Av. 14.86%); low to moderate concentrations of TiO_2 (0.03 to 1.62%; Av. 0.53%); low CaO (0.53 to 2.88%; Av. 1.44%); low MgO (except one sample which has high MgO concentration of 5.23%; 0.03 to 5.23%; Av. 0.82%); variable but moderate to high levels of alkalies (Na_2O range from 1.79 to 4.80%, Av. 3.12%; K_2O varies from 1.51 to 8.14%; Av. 5.61%) with low to moderate levels of $Fe_2O_3^T$ (0.85 to 9.43%; Av. 3.57%). The average composition of these gneisses are remarkably similar to the average A-type granite (Table 3). Thus, these compositions reflect on the petrogenetic aspects of these gneisses. Similarly the trace element compositions exhibit significant variations, particularly in the case of Rb, Sr, Y, Zr and to certain extent in Nb, Cs, Ba, Hf and Ta as also U and Th (Table 1). The Na_2O–K_2O relationship in these gneisses assigns a predominantly granite- to quartz-monzonite character to them (Figure 2). On the AFM ($Na_2O + K_2O$–$Fe_2O_3^T$–MgO) plot they depict a calc-alkaline character (Figure 3).

La_N/Sm_N which indicates LREE fractionation has a positive correlation with SiO_2. However, at higher SiO_2 levels the trend is not evident, with large variation in La_N/Sm_N. On the other hand Ce_N/Yb_N tends to be low at higher SiO_2 levels (Figure 4). Similarly Gd_N/Yb_N which is indicative of HREE fractionation has a broad negative correlation.

The chondrite-normalized rare earth element patterns of these gneisses suggest overall fractionation of REE (Figure 5); LREE enrichment and fractionation are evident ($Ce_N/Yb_N = 0.79$ to 49.98; Av. 14.77); significant negative Eu anomalies are discernible except in

Table 3. Range and average chemical compositions of the Tirodi gneiss and average compositions of different granite types

Wt%	Tirodi gneiss Min	Max	Avg	A-type granite	I-type granite	S-type granite
SiO_2	59.07	75.69	70.59	73.60	67.98	69.08
Al_2O_3	13.37	16.56	14.86	12.69	14.49	14.30
TiO_2	0.03	1.62	0.53	0.33	0.45	0.55
CaO	0.53	2.88	1.44	1.09	3.78	2.49
MgO	0.03	5.23	0.82	0.33	1.75	1.82
Fe_2O_3	0.85*	9.43*	3.57*	0.99	1.27	0.73
FeO	–	–	–	1.72	1.27	3.23
Na_2O	1.79	4.80	3.12	3.34	2.95	2.20
K_2O	1.51	8.14	5.61	4.51	3.05	3.69
MnO	0.02	0.21	0.06	0.06	0.08	0.06
P_2O_5	0.01	0.30	0.09	0.09	0.11	0.13
A/CNK	1.00	1.47	1.08	1.03	0.96	1.18
Sc (ppm)	1.00	18.00	10.00	14.00	15.00	14.00
V	1.00	52.00	13.60	10.00	74.00	72.00
Cr	4.00	51.00	10.65	3.00	27.00	46.00
Ni	1.00	26.00	8.40	2.00	9.00	17.00
Cu	1.00	20.00	3.10	6.00	11.00	12.00
Ga	11.00	89.00	31.95	21.00	16.00	17.00
Rb	94.00	317.00	220.01	199.00	132.00	180.00
Sr	6.00	349.00	94.55	105.00	253.00	139.00
Y	9.00	111.00	50.90	76.00	27.00	32.00
Zr	17.00	877.00	346.60	342.00	143.00	170.00
Nb	1.00	281.00	31.30	22.00	9.00	11.00
Ba	83.00	1723.00	399.70	605.00	520.00	480.00
Th	1.00	100.00	35.60	105.00	16.00	19.00
U	1.00	14.00	4.15	23.00	3.00	3.00
La	5.21	264.54	76.63	55.00	29.00	31.00
Ce	12.83	388.18	130.93	134.00	63.00	69.00
Nd	7.38	122.03	47.78	56.00	23.00	25.00

*Fe_2O_3 as total iron.

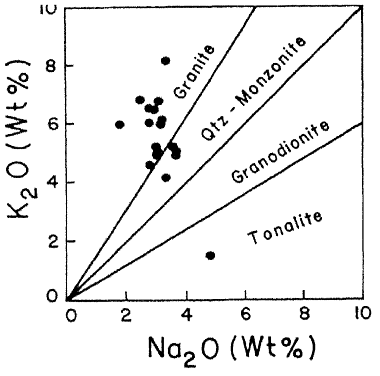

Figure 2. Na_2O–K_2O relationship in the Tirodi gneiss depicting a granitic- to quartz-monzonite character except one sample which shows tonalite character.

one sample with significant positive anomaly (Eu/Eu* = 0.04–1.78; Av. 0.43). ΣREE varies from 49.89 to 897.07 ppm with an average of 305.89 ppm.

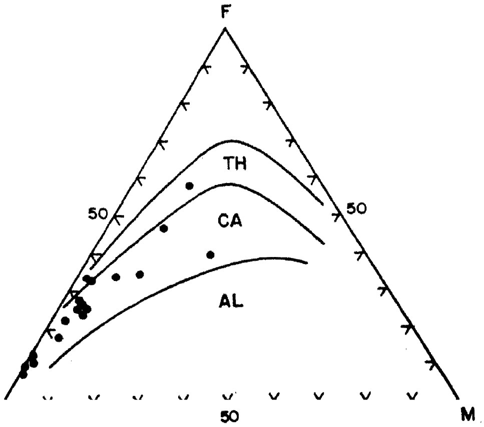

Figure 3. Alkalies – total iron as Fe_2O_3–MgO (AFM) ternary diagram showing mainly calk-alkaline fractionation trend for the protoliths of the Tirodi gneiss.

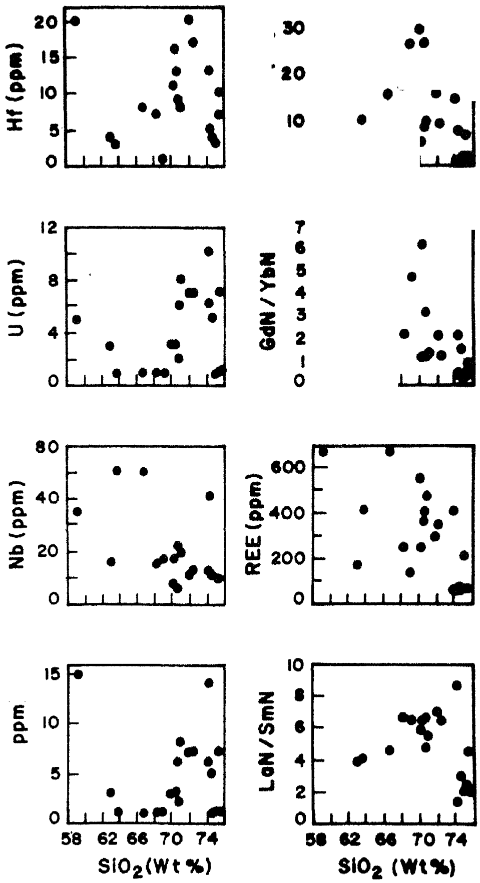

Figure 4. Variation diagram showing the relationship of SiO_2 with Th, Nb, U and Hf and REE ratios.

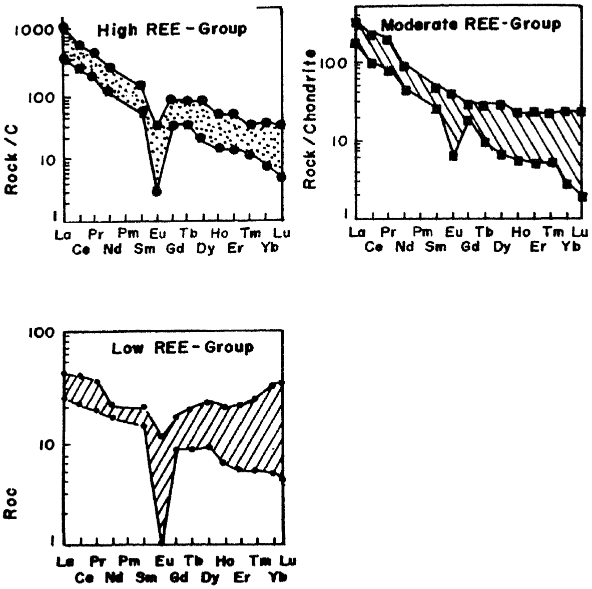

Figure 5. Chondrite normalized REE patterns of the Tirodi gneiss with all the three groups showing negative Eu anomalies of varying degrees.

K/Rb in these gneisses varies from 82 to 441, with an average K/Rb of 224, which is quite similar to the reported upper crustal K/Rb of 230. These gneisses are characterized by relatively enriched large ion lithophile elements (LILE) like K, Rb, Ba, Cs, U and Th, similar to the acid igneous rocks of the upper crustal regions.

These variations suggest that the LILE geochemistry is probably not significantly affected by post-formational changes and reflect their original nature, since these gneisses are not characterized by metamorphism of any significantly high grade. Moreover, the variations in the high field strength (HFS) elements as also the REE compositions suggest derivation from mixed and evolved source regions.

These gneisses can be divided into three groups with respect to their total REE contents and chondrite-normalized rare earth element patterns, i.e. a high REE group, a moderate REE group and a low REE group (Figure 5). Almost all the groups exhibit negative Eu anomalies (with the exception of one sample), though of different extent in the three groups, and varying degrees of LREE and HREE fractionation.

Based on the relationship of 10000*Ga/Al vs Nb, Ce, Zr and Y, most of the samples fall in the A-type granite field, with only a few samples tending to be I- and S-type granites (Figure 6). Similarly the plot of Zr + Nb + Ce + Y vs 10000*Ga/Al suggest an A-type character for these gneisses (Figure 7). On the tectonic discrimination plots, these gneisses indicate a within-plate granite (WPG) character[5], with only a few samples straddling the volcanic arc granites (VAG) and syn-collision granite (syn-COLG) fields (Figure 8). On the ternary plot involving Y-Nb-3Ga, these gneisses overwhelmingly fall in the A2 group of the A-type granites (figure not shown). They are characterized by high SiO_2, Na_2O, K_2O and are relatively low in MgO, CaO and P_2O_5. Similarly, among trace elements Rb, Zr, Y, Nb, LREE and Ga are enriched in these gneisses, while Sr, Eu, Sc, V, Ni and Cr are relatively low (Tables 1 and 2). Negative Eu anomalies, high ratios of Rb/Sr, K/Rb, Ga/Al, Zr/Ni, Y/Sc and high Zr + Nb + Y + Ce are recorded, which distinguish these gneisses from I- and S-type magmas[6–13]. All the samples have consistently high Ga values (ranging from 11 to 89 ppm) and usually high ratios of 10000*Ga/Al (1.48–10.46). The average composition of the Tirodi gneisses resembles the average 'A-type granite' in several respects (Table 3), apart from most of the samples falling in the A-type granite field

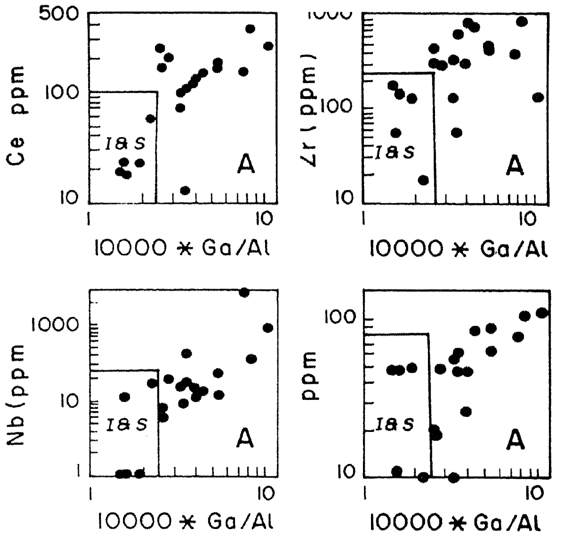

Figure 6. 10000*Ga/Al vs Nb, Ce, Y and Zr in the Tirodi gneiss suggesting their mainly A-type granite character. I, I-type granite; S, S-type granite.

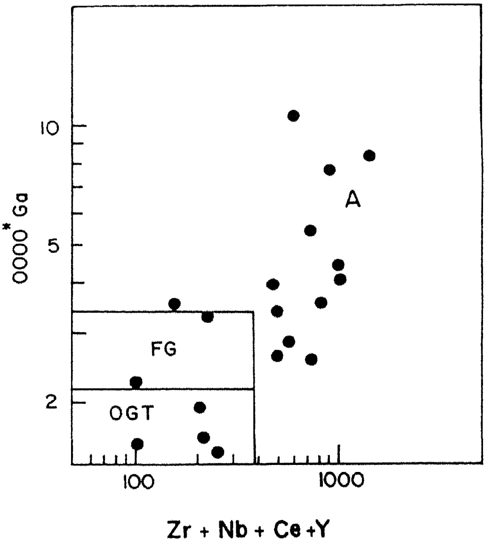

Figure 7. Zr + Nb + Ce + Y vs 10000*Ga/Al in the Tirodi gneisses indicating the predominantly A-type character of these gneisses. FG, Fractionated Granites; OGT, Other granite types.

and the 'within plate granite' side in the tectonic discrimination diagrams[5]. Enrichment in high field strength elements (HFSE) is a characteristic feature of these gneisses. The concentrations and ratios of several HFS elements which are considered relatively immobile during most alteration and metamorphic processes may be more reliable[14].

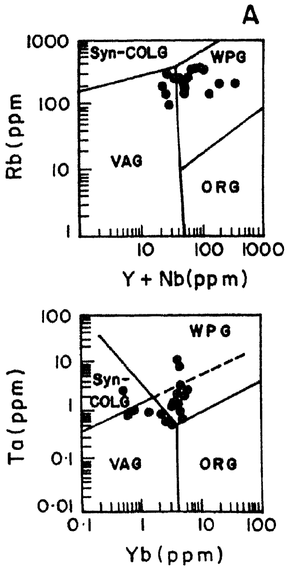

Figure 8. Tectonic discrimination diagrams (A = Y + Nb vs Rb; B = Yb vs Ta) for the Tirodi gneisses, indicating their predominantly within plate granite nature. VAG, Volcanic arc granite; syn-COLG, Syn-collision granites.

As A-type granites occur in non-orogenic settings, both within plate and along margins during the waning stages of subduction related magmatism, the possibility of a petrogenetic link between these granitic gneisses and the accretionary tectonics of the Central Indian region cannot be ruled out. The Dongargarh Super Group metavolcanics, particularly the Khairagarh volcanics are stratigraphically equivalent to the Sausars. They are considered to be the products of subduction related volcanism[15,16]. The emplacement of the volcanics might have supplied the necessary heat required for melting the lower crustal rocks. The occurrence of granulites in close proximity to these gneisses also supports the origin of the protoliths for the Tirodi gneisses from lower crustal source region. The protoliths of the Tirodi gneisses could be products of lower crustal melting. The necessary fluids required for enabling the resultant melt get enriched in the incompatible and HFS elements might have been provided by the basic magma. The Nb-Y-3Ga relationship as also the Nb-Y-Ce relationship in these gneisses suggest that they possibly belong to the A2-type granites which can form by the involvement of magma generated by continental margin and island-arc basalts, possibly during the waning stages of subduction or non-orogenic setting in a marginal basin environment. Such felsic magmas are normally produced during the rapid development of island arc/back-arc basin system via extension within the margin of a pre-existing older continental crust. Sedimentation and magmatic activity within the basin ceases on closure of the back-arc basin and accretion of the crust in the Proterozoic[14].

A-type granite plutonism usually, though not exclusively, occurs in rift related environments in continental crustal regions. The production of anorogenic granite magma requires: (i) a source of dehydrated, reasonably salic crust; (ii) a source of heat sufficient to partially melt this crust; and (iii) a conduit to lead the magma to a higher level[9,10]. Such a scenario could be envisaged for the petrogenesis of the protoliths of the Tirodi gneisses. A plausible petrogenetic model for the origin of the protoliths for these granitic gneisses could be their derivation by extended fractional crystallization of a melt generated at lower crustal levels, contemporaneous with basalt emplacement in a rift-related extensional environment. Initial deposition of the sedimentary sequence of the Sausar Group might have started prior to the emplacement of the granitic melt, leading to a limited assimilation of the sediments already in place. That is possibly why some samples of the Tirodi gneiss unit tend towards the 'syn-collision' and 'volcanic arc' granite fields on the tectonic discrimination diagrams (Figure 8) and show a limited affinity towards the I- and S-type granites (Figure 6), though the overall A-type character is evident. There is a general high degree of concordance between Y/Nb and Yb/Ta ratios, which is the case in several A-type granite suites. Similarly Y-Yb and Nb-Ta show geochemically similar behaviour and these pairs of elements show concordance, as is also the case in several A-type granites. A detailed look at the overall and average compositions of the Tirodi gneiss unit brings out the remarkable similarities in several respects to the A-type granite (Table 3). The similarities are more striking in the case of CaO, Iron, Na_2O, K_2O, Ga, Rb, Y, Zr, La, Ce and Nd. Enrichment of HFS elements is a characteristic feature of these gneisses like in the A-type granites. The geochemical fingerprints in the Tirodi gneisses as mentioned above are consistent with the mixing of a newly mantle-derived component with an older crustal component through lower crustal assimilation and possibly the sediments of the Sausar Group on a limited scale, as suggested by the somewhat lower levels of Ba, U and Th and the moderate-to-high Al_2O_3 levels in these gneisses compared to the average A-type granite and the fact that some samples of these gneisses fall outside the 'A-type granite' and 'within plate granite' fields (Figure 6). The lithological configuration of the Central Indian craton suggests such a tectonic environment as can be seen from the occurrence of the subduction-related basic volcanism and the amphibolites which exhibit formation in a continental margin tectonic setting and a back-arc basin tectonic environment respectively[16,17].

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Nonsense in Indian Science. Dilip M. Salwi. Konark Publishers Pvt. Ltd., A-149 Main Vikas Marg, Delhi 110 092, India. 1998. 124 pp. Price: Rs 125.

That a review of a book should be reviewed in turn is unusual. And the fact that the original review appeared in *Nature* – no less – and that the 'review of the review 'appeared in *Current Science* – no less – is even more so. It was therefore a delightful surprise to lay my hands on the book, in the British Council library in Delhi (which is again unusual, since the library's policy is to stock British publications almost exclusively), just as I was looking for something interesting to read on a journey. However, less than an hour into the journey and I was already done with the book, wondering what men of stature could possibly have seen in this haphazard collection of paragraphs that they decided to lavish on that collection precious journal space and their time.

A book that prints an apology in the place normally devoted to a preface suggests humility, if nothing else. The apology goes on to say: 'there is no such thing as "Indian science" or "Australian science" or for that matter "Western science". Science is science – the country where it is practised does not matter. In this book, "Indian science" refers to the typical cultural practices followed by Indian scientists'. The author then adds that his 'nine years of observing, noting and studying the behaviour and practices followed by Indian scientists in their labs and outside' would be more than fulfilled if this book inspires anyone to revamp the present system of scientific research. The book's purpose is stated plainly enough: 'It is a fun book. I have tried to pose the various problems and malaises that afflict Indian science by portraying them in a satirical manner. I hope through this style people at large and authorities in particular would become aware of them and do something concrete.'

However, instead of the promised satirical portrayal of problems, what meets the reader is a catalogue of grouses – nepotism, mediocre performance, sloth, indifference, avarice, to name a few – that are exclusive neither to India nor to its science. And what we get in place of witty satire is bland text excessively peppered with exclamation marks and interspersed with pointless and awkward cartoons. Whereas R. K. Laxman was incisive and brilliant in his *Science Smiles*, the present book is pedestrian in approach, sloppy in organization, and run-of-the-mill in expression. In vain does the reader look for the biting humour as seen, for example, in the passage in C. Northcote Parkinson's *Inlaws and Outlaws* on why journals proliferate, where the punchline reads: '... whose work is original only in grammar and punctuation.'

The following two items are typical and well-suited to convey the flavour of the book. They have been reproduced exactly as they appear in the original, with all the exclamation marks retained.

> Power is Knowledge!
>
> If a carcass is needed to stir up the people, I will donate mine. *Everiste Galois.*
>
> "Knowledge is power" was uttered by that great scientist and statesman Benjamin Franklin. But, perhaps, he had not seen the manner in which scientific organizations and labs in India are handled. Had he seen that he might have uttered the reverse of it, i.e., "Power is knowledge"!
>
> In fact, these three words express all those things for which Indian labs and organizations stand. These are the places where power rules the roost; where power forces knowledge to lie low; where knowledge stoops before power; etc.!
>
> Permit for Reading!
>
> Where ignorance is bliss, it is folly to be wise. *Thomas Gray*
>
> If you want to enter the portals of a library of a research institute, you need to have a permit as though scientists are doing something secret inside it! It is a crime to be there without the permit! You must first identify yourself and establish your credentials before it is issued to you.
>
> Thereafter, even if you tear off pages from books and journals, it is none of their business! Just ensure that the tranquility of the library, the librarian and the library attendants is not disturbed!

Salwi writes with insider knowledge. His forays into the world of Indian science have served him well in choosing the topics but he has failed to develop and organize them. The book would have been particularly well-served by anecdotes, making it more concrete, realistic, and interesting. After all, for such a practised writer, it would have been easy enough to recount actual incidents after dressing them up to 'protect the guilty'. But the author did not choose to do so, presumably out of a misplaced preference for anonymity. The result is a particularly bland presentation, with no details at all, that reads more like the anonymous denouncements that turn up often enough in any large establishment, scientific or otherwise, than the lively prose of an accomplished writer.

If the text shows a failure to develop the topics, the table of contents (which runs to six pages – remarkable for a 124-page book with illustrations), shows up the quirky organization of the book. The book is a collection of 155 headings, under each of which appear one or more paragraphs, similar to the representative sample reproduced earlier. These headings are presented under 14 major categories, somewhat like the chapters of a book. In some chapters, such text is subdivided further into several sections; in some, it is not further divided at all; in some others, the organization is peculiar: there is a chapter title all right but instead of subdividing the contents of the chapter into two or more groups, all of it appears under yet another category, and it is not clear how that category fits into the overall organization of the chapter. (For instance, all the three sections in a chapter titled 'Bureaucratic juggling' are grouped under only one heading, namely 'Hunting for Funds', indicating that hunting for funds is one form of bureaucratic juggling: but what are the others, if any?) To me, such arrangement shows want of care in organizing the book. Even this semblance of a structure breaks down on closer scrutiny when you begin to look for logic: Why are the chapters arranged in the given order? On what basis have the 155 headings been distributed among the chapters? The inescapable conclusion is that the book is simply a collection of headings, each one fleshed out with one quotation and variable amount of text ranging from as few as 4 lines to as many as 70 or so.

When you consider that headings are set out in large type, with generous space all around, it is clear that they serve as padding. Add to that the space taken up by the quotations and the cartoons, and you wonder whether the matter was enough to make even a booklet, let alone a full-length book.

But what is the book all about? The title tells you little. The copy on the inside flap tells you that the book is 'essentially meant to be a fun book, but it subtly aims to wake up the reader to the harsh realities of Indian science'. As you begin reading the book, you realize that it is written in the 'rant mode', a litany of woes that beset Indian science: lack of teamwork, nepotism, mindless bureaucracy, lack of commitment,... . As I mentioned, the list runs to 155 points. Everyone who has served India's science establishment would agree with Salwi's list. But so would everyone who has served India's bureaucracy. The point is that these are the ills that are not unique to Indian science. Just as a scientist who wants to measure air pollution would distinguish between the 'background' level of pollution and that attributable to such specific sources as thermal power stations, we need to know what are the ills that are unique to Indian science. But *Nonsense in Indian Science* fails to tell us. Secondly, it restricts Indian science only to that carried out in state-funded laboratories, ignoring the pioneering contributions of many who worked on their own or were supported by entities other than the state. Science flourishes in this mode even now. Thirdly, in painting Indian science with such a broad brush, the author does injustice to the many who continue to serve Indian science despite crippling odds (though he dedicates the book 'to all those genuine scientists who are suffering due to organized scientific research'). Lastly, in one sweeping statement, he rubbishes all Indian women scientists: 'They (women scientists) simply want some pocket money for their upkeep and to buy sarees till their marriage – and sometimes even after their marriage!... they are often not ambitious in the sense that they are willing to yield their credit in research to their guides or bosses! Besides, which Indian scientist wouldn't like a pleasant face or female charm in his otherwise cut and dry, often monotonous, workaday scientific research? Women are therefore preferred in all laboratories!'.

That such blatant chauvinism made it past the editor is perhaps less surprising, given the numerous infelicities of expression that the book is riddled with.

Despite the high esteem that scientists enjoy (a recent survey by the *Times of India* reported that scientists scored well on such counts as honesty and respect for the profession), the book is a missed opportunity: the author chose a subject that needs a book to itself, was well-qualified to write one, and selected a 'treatment' that would have proved effective; the publisher was committed enough to publish the book despite what in all probability is only a small market. In doing so, both have done a service to India's science community. If the book prompts at least a few out of the thousands who make up India's science community, and those who administer it, to write at length about what ails Indian science and, more important, how to cure it of those ills – in a style not ponderous and abstract, nor acrimonious and self-centred, but lively and entertaining – the book will have served some purpose.

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Sandal and its Products. A. M. Radomiljac, H. S. Ananthapadmanabho, R. M. Welbourn and K. Satyanarayana Rao (eds). Australian Centre for International Agricultural Research, GPO Box 1571, Canberra ACT2601, Proceedings No. 84. 1998. 203 pp. Price not mentioned.

This is a collection of papers presented at an International Seminar held on 18 and 19 December 1997 at Bangalore, organized by the Institute of Wood Science and Technology, Bangalore and the Karnataka State Forest Department.

Sandalwood (technically the dead, heartwood) and its fragrant oil are two exquisite gifts from the orient to the world. Mysore has been historically associated with the sandal perfumes, agarbathies, carvings and soaps. The paste of sandalwood is used in religious ceremonies and in medicine. Sandalwood (*Santalum album*) is a rather unimpressive small tree (15–29 m high) that occurs wild in India in the regions adjoining Karanataka and Tamil Nadu. According to some authors sandal is native to India. Others believe that it was introduced from Timor Islands.

A book has to be judged on the basis of its contents and also in comparison with works published recently on the subject. An earlier publication on sandal, edited by Srinivasan *et al.* (1992) has covered aspects such as history, distribution, morphology, soil, sylviculture, physiology, chemistry and utilization, diseases and pests, tree improvement, production, export and management. Whereas it is an excellent compilation with a historical perspective, it concentrates entirely on sandalwood in India.

Sandal and its Products has a much wider canvas and deals with 16 species of *Santalum*, distributed in India, Australia, Papua New Guinea, New Caledonia and South Pacific Islands (as depicted in the frontispiece of the volume). If properly utilized on a sustainable basis, sandal has the potential to contribute significantly to rural economies of several countries in the Asia Pacific region. The objectives of the seminar were to bring together the current knowledge on silviculture, propagation, genetics, management of pests and diseases, biotechnology, utilization and importantly to identify the most crucial problems and constraints and recognize research needs and pinpoint priorities and suggest collaborative programmes.

The volume contains 51 articles – some highly technical and original, others general and review type. The editors have grouped them under 5 broad heads for convenience. The status of sandalwood in India has been assessed briefly and strategies for development of sandalwood in farm industry for sustainable utilization by the craftsmen have been outlined.

Among the various species of the genus, *S. album* is the principal source of wood and oil. It is a root parasite (has over 200 hosts) and occurs in forests as well as along fences in cultivated fields and in urban areas. The species is self-incompatible but sets a copious amount of seeds, disseminated by birds attracted by the sweet pulp in the berries. Recognizing the value of sandal as a generator of employment, and revenue (including foreign exchange), Karnataka has declared it as a government tree.

The laws regulating the production and handling of sandalwood are so stringent that large-scale decimation of trees and smuggling continue unabated and outlaws continue to pose a threat to the police and forest officials. Owing to the ban on export of sandalwood from India by the Central Government, international prices have gone up and synthetic santalol (considered inferior to the natural sandalwood oil by the manufacturers of high quality perfumes) and inferior woods of other species of *Santalum* and other genera are being substituted. The losses due to ban on export are serious. It is claimed that over 6000 tonnes of superior quality sandalwood are lying unused in the depots in Tamil Nadu alone, causing an annual loss of Rs 100 crores.

The paper by Kushalappa has underlined that the outmoded and impractical laws in Karnataka have been counterproductive and has advocated rethinking and liberalization of rules, regulations and restrictions. He argues that rosewood, catechu and teak trees are better looked after by private owners and their woods are not under severe threat like sandal.

Sandalwood is difficult to propagate vegetatively. Seed-raised plants are heterozygous. Owing to the excellent work done by P. S. Rao (BARC, Bombay) and Lakshmi Sita (IISc, Bangalore) and their associates, sandal can be micropropagated and the plantlets raised can be hardened and successfully transferred to field conditions. This volume includes several new reports on the same subject, including responses of tissues from healthy and diseased plants. Sandal is also one of the few tree species in which somatic embryos have been produced in bio-reactors and converted into artificial seeds.

There are serious attempts to introduce VAM fungi to the seedlings to ensure better survival, growth and yield under forest conditions. The role of nitrogen fixing and non-nitrogen fixing host plants on sandal has also been discussed. Till recently, the extraction of oil was based on traditional methods such as steam distillation and solvent extraction. The seminar proceedings report recently developed approaches to chemistry and utilization. The paper on the anatomy of sandalwood and identification of adulterants on the basis of wood structure is elegantly presented.

The most valuable part of the book relates to tree improvement. It deals with the identification of provenances; use of alloenzyme markers and their application in population genetics; floral biology and breeding systems. These are areas in which a positive effort can be made in India where trained human resource is available.

The spike disease has been a major scourge of sandalwood, taking a heavy toll of trees. Tips of shoots start bearing little leaves, causing a bushy appearance. At later stages the shoots become bare and sterile and the diseased plants add little heartwood. The nature of the disease and the physiological and biochemical changes caused in the tissues have been intensively investigated in IISc since the early 1930's. The causal organism of the spike disease is a phytoplasma (formerly also called mycoplasm-like-organism or MLO), confirmed by transmission electron microscopy. The unicellular, non-culturable phytoplasma can be specifically stained by using DAPI stain (4,6-diamidino-2-phenyl indole) under the fluorescence microscope. The paper by Sunil and Balasundaram demonstrates the localization of phytoplasma in the phloem tissues of infected plants. Sandal is also attacked by borers leading to die back and mortality of smaller trees. There are also reports that large quantities of heartwood stored in government depots in Tamil Nadu and Karnataka are damaged by borers and termites.

The excellent research done in India on sandal over the past six decades has had little impact in solving the wide range of problems facing this tree of immense cultural and commercial significance. It is time that problem-solving is given serious priority. The seminar has taken note of this malady. Besides suggesting collaborative research in areas that interface, the participants have identified gaps in our knowledge and have listed research needs in their recommendations.

Removal of restrictions on government ownership and encouragement to grow sandal trees on private lands in Karnataka would be measures that need immediate consideration. International support should be provided for evaluation of genetic resources (especially for resistance to spike disease), improvement, breeding, selection and commercial viability of tissue culture-raised plants cloned from exceptional individuals.

The volume has much valuable information and is elegantly produced with excellent illustrations. There are a few avoidable typographical errors, including the spelling of the name of one of the editors. I would recommend this book to foresters, geneticists, breeders, botanists, biotechnologists, pharmaceutical chemists, planners and decision makers.

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Geology of Andhra Pradesh. P. K. Ramam and V. N. Murthy. Geological Society of India, P. B. No. 1922, Gavipuram, P. O., Bangalore 560 019, India. 1997. 245 pp. Price: Rs 250.

The Geological Society of India has launched a programme to publish textbooks on the geology and/or mineral resources of the different states of the Indian Union and the present book *Geology of Andhra Pradesh* is one among the series of 9 that have so far been published. This book is organized into 16 chapters which cover the descriptions of the geological record from the Archaean to the Holocene time. The authors are experienced field geologists and though they state that the thrust of the presentation is on litho-stratigraphy and field relations (pp. 3–4), they have judiciously mixed the concept and the field data to achieve cogent presentation in the compilation.

There is unity in the operation of a geological process which is manifested worldwide though the type and/or magnitude of a particular process varied with geological time. Further the geological boundaries of the litho-stratigraphic units or tectono-metamorphic belts may transgress the political boundaries of the provinces (states) or the countries. In some states complete geological succession of an epoch/period could have developed which could be taken as typical for comparison, but all states contain fairly good record of the strata formed during one epoch/period or more that gives importance to the region. Andhra Pradesh (AP) by virtue of its location in peninsular India embodying defined tectonic elements contains fairly good record of the Archaean, the Middle–Upper Proterozoic and the Gondwana strata. During the last two decades substantial geological information came from at least three new areas in AP: the auriferous minor greenstone belts of Chittoor–Anantapur Districts, alkaline and other intrusive rocks of Prakasam District, and the sub-crop Tertiary sequences of coastal and off-shore K. G. basin. This has enhanced the importance of highlighting the regional aspects of the state's geology. All these are given due treatment in the book.

In southern peninsular India, the Archaean Schistose rocks and the Gneissic Complex of the Dharwar–Karnataka (craton) served as a reference standard for various reasons. The authors of the book have thus taken recourse to introduce the Archaean litho-stratigraphy of the Dharwar area before describing the schistose formations or the gneisses of AP in the related chapters. This is justified and more particularly so when the Archaean group of rocks of AP forms part of the Dharwar craton and that nearly two-thirds of the Eastern Block of Dharwar craton lies within AP and that itself constitutes 60% of the state (p. 10).

Chapter 1 gives an outline map of AP with district boundaries. Chapter 2 mentions the four tectonic sub-divisions of the state–Cratonic part, Marginal Transition Zone (MTZ), Godavari Graben and the Eastern Ghats Mobile Belt (EGMB). Chapter 3 gives a generalized summary of the litho-stratigraphic succession and the age data on dated rocks. In Table 2, there is a compiler's mistake in placing the formations of the Gondwana: Kota and Maleri against the appropriate row; Talchir, Barakar, Barren Measures and Kamthi under the appropriate column.

The minor schist belts of Veligallu, Gadwal, South Kolar belt (known earlier as Bisanattam schist belt), Kadiri, Ramagiri–Penakacherla, Jonnagiri and Peddavuru, which are equated with the Kolar-type auriferous greenstone (2700 M.a. age), are adequately described with geological sketch maps. The authors mention (p. 74) that the environment of the Ramagiri Schist Belt is that of island arc setting while the Kolar Schist Belt is that of the ocean floor. This is based on the geochemical studies of the associated basalts, but the two specific published papers related to these are not given under the references cited at the end of the Chapter 1. The supracrustal rocks of Nellore Schist Belt (NSB) and the Khammam Schist Belt (KSB) forming the MTZ are given full treatment. So also are the newly found Karimnagar Granulite Belt (KGB) and the counterpart Bhopalpatnam Granulite Belt (BGB) across the Gondwana of the Godavari valley in Bastar. In Figure 15, extension of KSB north of the Gondwana in Khammam district should be shown as the supracrustals of Mailaram part of this belt with copper mineralization occurring here. This extension, however appears in the coloured geological map of AP (opposite p. 18).

The Eastern Ghats is a prominent belt in AP extending NE–SW for 600 km in the state along the coast with a width varying from 100 km to 20 km. This belt continues to defy systematization of the litho-stratigraphy and tectonic interpretation with dated ages spreading from 2600 M.a. to 500 M.a. In chapter 5, the authors have adopted a division of the Eastern Ghats Belt into three longitudinal zones, the Western (WCZ), the Central (CKZ) and the Eastern (EMZ) based on the relatively greater occurrence of the Charnockite, Khondalite and Migmatite in the respective order. The Charnockite Region of Fermor of high grade granulites in peninsular India is re-defined in recent years principally based on the work in southern Karnataka and the northern Tamil Nadu and in this exercise the Eastern Ghats Granulite Belt (EGGB) is described as the Middle Proterozoic Mobile Belt (MPMB) or Eastern Ghats Mobile Belt (EGMB). In recent years a lot of work on the Granulite Belts and their fit in a reconstructed East Gondwana Continent (EGC) has been carried. A map showing the position and fit of EGGB with the granulite belts of EGC could be given.

The Gneissic Complex which constitutes a very large part of the state is classified into Penninsular Gneiss (chapter 6) and Younger Granites (chapter 7). Geological information on the distribution of these two types covering the entire state is still incomplete partly due to their field disposition with frequent intermixing and migmatization on various scales. Consequently, the two types appear as one unit of Unclassified Crystallines (Gneissic Complex) in the coloured geological map of AP (opposite p. 18). As described by the authors petrologically, there is worldwide recognition from the studies on different shield areas that Na-rich granitic rocks of tonalite-trondhjemite-granodiorite (TTG) are Early (> 3400 M.a.) to Middle Archaean (3400–2800 M.a.) in age, the tonalite granodiorite-adamellite (TGA) and the granodiorite–adamellite granite (CAG) are mostly Middle Archaean in age, while K-rich granite-adamellite (KGA) are mostly Late Archaean (2800–2500 M.a.) to Palaeo–Proterozoic (2500–1600 M.a.) in age. In classifying the Gneissic Complex of AP, the authors have retained the term Peninsular Gneiss for all the granite gneisses of the above petrological types (like the TTG south of Mahabubnagar) other than KGA, while the latter is put under younger Granites (like the KGA of Anantapur) corresponding largely to the well-known Closepet granite of Karanataka. In chapter 8, mafic dyke swarms largely made up of dolerites of Meso–Proterozoic age (1600–950 M.a.) are described along with a map of their distribution west and south of the Cuddapah basin based on the LANDSAT image and these dykes show the dominant E–W trend.

Chapter 9 describes the Purana basins of Cuddapah, Pakhal and Bhima containing the strata of Meso–Proterozoic age (1600–950 M.a.) and/or Neo–Proterozoic age (950–550 M.a.). Cuddapah is a very prominent basin in AP and King's classification of the strata withstood for a century. With the results of detailed mapping of the Cuddapah basin by GSI during the last two decades and their classification of the strata in accordance with the international code of stratigraphic nomenclature, the authors have rightly adopted the revised litho-stratigraphic classification of the Cuddapah basin. Probably they could have also given the classification of King for comparison and explained the changed status of certain Formations of the Cuddapah Supergroup just as they cited the one for the Kurnool Group (p. 127). In the revised litho-stratigraphy given in the coloured map of the Cuddapah basin (opposite p. 122), the Srisailam Quartzite which has a Formation status is inadvertantly bracketed with the Kurnool Group, instead of the Cuddapah Supergroup. In the Pakhal basin, folding and metamorphism is confined to the south-eastern end of the belt around Yellandlapad in Khammam district. There is no development of kyanite in the Pakhals as stated (p. 142), but ottrelite is reported from the Pakhals which is not mentioned or cited under the references.

In chapter 10, the Middle to Late (Meso- to Neo-) Proterozoic igneous activity of alkaline rocks of Prakasam district, the cratonic kimberlite diatremes and dykes of Anantapur, Kurnool and Mahabubnagar districts, the pegmatites of NSB and rocks suspected to be carbonatics from Visakhapatnam and Nellore Districts are described. In chapter 11, the Gondwana of the Godavari valley of Palaeozoic–Mesozoic age is described incorporating some revision of the stratigraphy in the Chintalapudi sub-basin. The description on the boundaries of the sub-basins of the Gondwana and the faults in the Godavari valley (pp. 170–171) could be appreciated better if the related map with names is given and the reference is duly cited at the end. In chapter 12, the Deccan trap volcanic activity at the Crataceous–Tertiary Boundary (KTB) is described mentioning the number of flows up to eight encountered in the drilling in the KG basin by ONGC. A general view on the linkage of Deccan volcanism in India to the movement of the Indian plate over the Reunion hotspot is also given. In chapter 13, the Tertiary rocks, principally the Middle Miocene Rajahmundry sandstone are described. In chapter 14, the Quaternary geology is described. The occurrence of oolites in the present outer shelf off Visakhapatnam reported in marine geological publications could be cited as evidence for the lowering of the sea level during Pleistocene. In chapter 15, the sub-surface geology containing the hydrocarbon-bearing Tertiary strata of the coastal and off-shore KG basin is adequately described giving suitable sketch maps. The last chapter gives an account of the geomorphology and soils of the state.

In any attempt of this nature, there is always a scope for improvement. The references could be better organized. A few field photographs could be included. The book is well-written and is readable. It brings out up-dated regional geological information under one cover and is very useful to students of geology and related branches of earth sciences.

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Erratum

Mechanism of ATP synthesis by proton motive force

H. Rohatgi, A. Saha and S. Nath

[*Curr. Sci.*, 1998, **75**, 716–718]

The numbering of amino acid residues of the ε subunit of ATP synthase corresponds to *Escherichia coli* (and not to bovine heart mitochondria, as inadvertently implied). Thus, lines 36–37 on p. 718 should read, 'Further Ser-108 of the rotating ε subunit (*Escherichia coli* numbering) interacts covalently[14,17] with Glu-381 (*Escherichia coli* numbering, corresponding to Glu-395 in bovine heart mitochondria) of β_E...' Similarly, in Figure 1, the numbering of the important amino acid residues is for *Escherichia coli*, while the labeling in the Figure is for mitochondria. Therefore, in Figure 1, the label, 'Inner membrane' should be substituted by 'Inner membrane/periplasm', while the label, 'Matrix' should be replaced by 'Matrix/cytoplasm'. The second line in the legend to Figure 1 should read, 'The important amino acid residues are shown.' These corrections do not in any way alter the results or conclusions of our communication.

Correction

The debate on the dawn of multicellular life on earth

A. V. Sankaran

[*Curr. Sci.*, 1999, **76**, 137–141]

I am thankful to Dr Vishwakarma for pointing out an error which had unfortunately crept in my paper due to oversight. The pertinent observation about the age of the Semri Group in relation to the kimberlite intrusion was indeed made by him in his paper *Curr. Sci.*, 1998, **75**, 1297–1300. My reference to this view of Vishwakarma in my paper on page 141, wrongly numbered as 21, should be corrected to No. 23.

Kaushal Kishore – An obituary

The last time I saw Kaushal Kishore was on Monday, just a day before he died, working away in his characteristic style till late at night. I am told he left the department after midnight, and on reaching home he complained of some breathing discomfort and was rushed to the hospital only to be pronounced dead. The way I saw him the following day – in his white *achkan* and *kurtha*, is how I shall always remember him. In this – his holiday dressing style, his politeness and his love for Urdu, he was always a *Lucknowi*. He died on 2 March 1999, the day of Holi–a joyous festival day when all his students wait in expectation of sweets he fondly treated them to – specially prepared at home year after year. I wonder if his passionately diligent nature had anything to do with this untimely death that cruelly cut short a very prolific career in polymer physical chemistry and chemical thermodynamics.

Kishore received his early education in chemistry from Lucknow University, and his Ph D from the Gorakhpur University under the guidance of the distinguished physical chemist, R. P. Rastogi. His thesis dealt with the mechanism of combustion of non-hypergolic propellants. After a brief stint at Gorakhpur University, he moved to the Department of Inorganic and Physical Chemistry, at the Indian Institute of Science (IISc) in 1974. He also served as the head of the department during 1994–1998.

Kishore started his career at IISc working on the kinetics and thermodynamics of combustion, specifically as it related to solid propellants. During this early period, he collaborated with Pai Vernekar on several projects on solid propellants that were funded by ISRO and DRDO. His work in this area led to several novel discoveries that shed light on the role of various components in such solid propellants. One was the finding that the polymeric binders used in these systems undergo several chemical transformations during combustion and also as a result of aging leading to the generation of polyperoxides. He showed that these polyperoxides caused an accelerated combustion in such solid propellant compositions. With this insight, he soon discovered a phenomenon unique to these polymers, that he termed 'autopyrolysis', which catapulted him to fame. His continued interest in this new class of polyperoxides, led to many other new research directions which helped in understanding both the polymer formation process as well as in developing potential applications for this class of polymers. Thus, in his early work, he brought to bear upon the phenomenon of combustion his deep understanding of chemical thermodynamics to formulate, quantify and provide a detailed mechanistic insight into the complex process of combustion, especially in composite formulations such as solid propellants. This led to many years of fruitful collaborations between his group and both the defense laboratories and ISRO, which lasted even during his last days at IISc.

The knowledge of combustion and flammability of polymers naturally led him to another 'burning' issue and that was flammability of synthetic polymers – on how to inhibit or suppress combustion. Given the contextual importance of this topic, he soon designed and tested various models for assessing the flammability of combustible materials and defined a new dimensionless quantity he termed 'Flammability Index'. Further, he went on to design new additives that would retard/inhibit the flammability of various polymeric materials. His interest in understanding the effect of such additives on the various properties of polymers, primarily on the lowering of their glass transition temperature (T_g), led him to yet another topical area in polymer science – plasticization. Some of his early work on studying phosphorous containing additives that act as both plasticizers and flame-retardants is well acclaimed.

His interest in the later years primarily focused on two subjects – one was related to the mechanism of plasticization in polymers and the other to polymer degradation. His was a search for a molecular basis for the plasticization of polymers. To this end, he designed several novel plasticizers with different molecular topologies and attempted to relate various macroscopic characteristics, such as their flow behaviour to the effectiveness in plasticising PVC, in particular. His efforts in designing polymers similar to polyperoxides, which he termed 'weak-link' polymers, drew his attention to analogous systems, such as polydisulfides. His most recent effort in this area primarily addressed issues related to the degradation mechanism of these weak link polymers – here again attempting to relate the mechanism to the intrinsic bond energies and heats of formation.

Kishore's work was always characterized by its ingenuity, depth and simplicity of analysis. He saw science in everything and had a strong conviction and motivation to understand all phenomena he observed at the microscopic, and if possible at a molecular level. His solid foundation in chemical thermodynamics brought to polymer chemistry a much-needed 'thermodynamic bias' – a term he often used to characterize his work. Using numerous tools, starting from thermoanalytical methods, rheological measurements, NMR and computational methods, he attacked his problems with passion and a characteristic zeal – which often culminated in nailing the issue on the head. Kishore

was extremely industrious, and often worked in the lab till the wee hours of the morning, writing papers, reading journals and discussing science with his students. His students will always remember him with fondness – for he was not only their research guide but also their friend and a confidant.

Recognition for his achievements came in many forms. Kishore was awarded the Bhatnagar prize in 1988, was elected to the Fellowship of the Indian Academy of Sciences in 1991 and most recently to the Indian National Science Academy in 1999. He has also been on the editorial board of the *Journal of Applied Polymer Science*, since 1995. Kishore served on several important decision-making bodies in the country – various assessment committees, research councils of national laboratories etc. His later years were turning out to be busier than he probably would have liked it, requiring him to take up frequent travel. He often joked that the security guards at the airport mistook him for someone very important and would stand in attention whenever he passed by. His stature and personality, without his knowing, often generated this reaction – little did they know of the gentle soul within.

Kishore enjoyed company and had a great sense of humor – even when he was the subject of the joke. He enjoyed good food, was a avid cricket fan with an enviable knowledge of cricket statistics and great lover of Hindi cinema – all of it – from the days when he was a teenager to the current ones, something very few of us can boast of. This speaks volumes about his personality – a willingness to adapt to the changing times. Kishore will be deeply missed by all those who knew him, more so by his colleagues, staff and students, for whom he is irreplaceable. The loss to Indian science, to say the least, is irreparable.

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MEETINGS/SYMPOSIA/SEMINARS

International Symposium and Field Workshop on Geodynamic Evolution of Himalaya–Karakoram–Eastern Syntaxis (Indo-Burma Range)–Andaman Nicobar Island Arc and Adjoining Region

Date: 11–16 December 2000
Place: Lucknow, India

Themes include: Palaeontology and stratigraphy; Palaeofloristics, palaeogeography, palaeoclimate and depositional environment; Accretion of Karakoram terrane; Origin and evolution of Himalaya-Karakoram-Eastern Syntaxis-Andaman Nicobar Island Arc; Hydrocarbon prospects in Andaman & Nicobar Islands and offshore region; Studies in Indo-Pacific region based on DSDP & ODP.

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Fifth Biennial Conference on Signal Processing and Communications (SPCOM '99)

Date: 21–24 July 1999
Place: Bangalore

Topics include: Signal processing algorithms & architectures; Image processing and vision; Nonlinear signal processing; Multirate DSP & wavelets; Time-frequency representation; Array signal processing; DSP applications; Wireless communications; Modulation, coding, encryption; Speech recognition; Speech and audio compression; Image and video compression; Biomedical signal processing; Multimedia signal processing.

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SATYENDRA NATH BOSE NATIONAL CENTRE
FOR BASIC SCIENCES

JD Block, Sector-III, Salt Lake, Calcutta-700 091

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(1999-2000 SESSION)

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Eligibility : Master's degree in Physics, Chemistry, Applied Mathematics/Engineering Sciences/M. Tech. (with good background in Physics). Candidates currently appearing in their final examinations may also apply.

Admission Test : Admission will be on the basis of academic record and performance in the admission test which will be held during early **June, 1999**. Candidates will be notified of the exact date. The session will commence in **August, 1999**.

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DEAN (ACADEMIC PROGRAMME)
Fax : 33-334 3477
E-Mail : abhijit@boson.bose.res.in

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Contact: Dr D. Das/Dr A. K. Ghosh
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aghosh@hijli.iitkgp.ernet.in

Transformation Biologists for Monsanto Research Centre, Bangalore

Monsanto Research Centre, Bangalore, is recruiting a Ph D scientist with experience to lead the Transformation Programme in ornamental plants. The position requires constant communication within the group and with various collaborators, particularly the team in St. Louis, USA. Excellent communication and leadership skills are essential. There is also an opening for M Sc level scientist in the area of sugarcane transformation.

Monsanto is a world leader in the discovery and development of agricultural products based on advanced chemistry and biotechnology. Monsanto has recently established a state-of-the-art research centre in Bangalore, which is conducting research on crop protection, genomics and transformation technology. The Centre seeks highly motivated professionals to work in an interactive team-based environment. Successful candidates will be responsible for the development and improvement of transformation systems to generate genetically modified crops.

Qualifications: Ph D degree from reputed Universities, in the area of tissue culture/plant transformation/regeneration for position 1 (ornamental plants) and M Sc in biological/life sciences with experience in similar areas as above, for position 2 (sugarcane). The responsibilities include developing, improving and evaluating transformation systems. The ability to work in a team-based environment and interactions with different groups are necessary. Additional consideration will be given to individuals with experience in ornamental crops for position 1 and in sugarcane for position 2.

National Physical Laboratory

Dr K. S. Krishnan Road, New Delhi 110 012

ADVERTISEMENT NO. 2/99

Applications are invited for the position of Research Associate under the DAE sponsored project entitled **Development of frequency stabilized diode laser for laser cooling of alkali atoms**, to be carried at NPL, New Delhi (a constituent laboratory of CSIR) as per details given hereunder:

Minimum Qualification: Ph D (Physics)

Fellowship: Rs 8000/- p.m. fixed; HRA, Medical allowance as per DAE rules.

Age: 35 years or below as on 1.1.99 (relaxable up to 5 years in the case of applicants belonging to SC/ST & physically handicapped categories and 3 years in the case of OBC candidates).

Special age relaxation: Up to the age of 40 years in the case of widows, divorced women and women judicially separated from their husbands who are not remarried.

The engagement for the post is under the sponsored project only and not against any vacant position in CSIR/NPL, temporary or otherwise. It is purely a contractual engagement for the project, funded by the above sponsors. It would, therefore not confer any right/claim implicit or explicit for consideration against any CSIR/NPL post.

The post is temporary for the duration of the project, which is to be completed by January 2002. The engagement is on contract for a specific period as mentioned above, which may be extended or curtailed at the discretion of the competent authority. In any event, engagement shall be co-terminus with the duration of the above mentioned project.

The applicants should submit their applications on plain paper duly typed, addressed to the Controller of Administration, National Physical Laboratory, Dr K. S. Krishnan Road, New Delhi 110 012, giving the following details viz.:

1. Advt. No.. Details of IPO...................................
2. Post applied for..
3. Name (in Block Letters) Mr/Miss/Mrs/Dr
4. Father's/Husband's name
5. (A) Date of Birth (B) Age as on 1.1.99
6. Postal & permanent address
7. Religion & caste (Whether SC/ST/OBC/PH)
8. University degree of higher education (Exam passes., subject, year, %age of marks Board/Univ.)
9. Particulars of Technical qualifications (Exam/Degree/Diploma, year, subject, %age of marks, Board/Univ.)
10. Research experience (attach supporting evidence), Number of papers published.
11. Have you ever been employed anywhere? (Name of the employer, period, salary, nature of duties, designation etc.)
12. Details of blood relations employed in CSIR/NPL.
13. List of enclosure
14. Signature of the candidate with date.

Affix your recent
passport size
photograph duly
signed.

Mere fulfilling the minimum prescribed qualification, etc. will not entitle the candidate to be called for interview since higher norms may be applied at the time of screening the applications. Complete applications duly supported by attested copies of the certificates and testimonials along with fee of Rs 25/- (rupees twenty five only) in the form of crossed Indian Postal Order payable to the Director, NPL, New Delhi should reach the controller of Administration at the above mentioned address within 21 days from the date of publication of this advertisement.

LATE APPLICATIONS/INCOMPLETE APPLICATIONS/INTERIM ENQUIRES WILL NOT BE ENTERTAINED.

Government of Kerala
Science, Technology & Environment (A) Department

Post: Director, Tropical Botanic Garden & Research Institute

Applications are invited for the Post of Director, Tropical Botanic Garden and Research Institute (TBGRI), an autonomous Research Institute established by the Government of Kerala under the Science, Technology and Environment Department. The Institute is responsible for carrying out research on all aspects of Botanical Research with particular relevance to Kerala.

The Director is the Chief Executive, with full authority and responsibility to organise and manage the staff, finances, facilities and services of the Institute, to meet its goals and objectives within the policy guidelines set for by the governing body nominated by the Government. The candidate must possess a doctorate degree in Botany or any branches related to Botany. He/she must have a broad scientific and technological vision related to Botany with proven ability to promote high quality research as well as development and transfer of technology. In setting research priorities, the Director, shall work in close liaison with the State Departments.

Candidates must be preferably below 55 years of age. The scale of pay is Rs 18,400–22,400 with allowances as per CSIR norms. Appointment will be made on contract basis.

Applications with complete bio-data and list of Scientific Publications may be sent to the Director, Science, Technology and Environment Department, Government of Kerala, II Floor, CMD Buildings, Thycaud, Thiruvananthapuram 695 014, within 15 days from the date of publication of this advertisement.

Sd-/
Chairman, STEC & Ex-officio Principal
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On the occasion of the Birth Centenary of Dr K. S. Krishnan, the Board of Research in Nuclear Sciences (BRNS) of the Department of Atomic Energy (DAE) introduces a prestigious scheme called 'Dr K. S. Krishnan Research Associateship'.

Under this scheme up to 20 Research Associates would be inducted every year with the possibility of getting absorbed in one of the R&D organizations of the DAE against regular vacancies based on their performance and evaluation during the period of their associateship. The associateships are available in the following broad disciplines.

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   ii. ENGINEERING: Masters degree in Engineering or Technology with 2 years experience in research, design, development or field work **OR** Ph D in the relevant subject.

Those who have submitted the doctoral thesis and are awaiting results may also apply.

Candidates must have an excellent academic record throughout their career.

b) *Age:* Not more than 30 years as on 1 October 1999. Relaxable by 5 years for SC/ST candidates and 3 years for OBC candidates.

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Eligible candidates will be called to appear for an interview in Mumbai. Preference will be given to those candidates whose research interest and work experience has relevance to the mandate of DAE. Outstation candidates will be paid sleeper class train fare or actual fare, whichever is lower. Candidates are advised to come prepared to stay in Mumbai for 2 to 3 days as a few shortlisted candidates will be asked to undergo a comprehensive medical examination on the day following the interview. Final selection will be made from among the shortlisted candidates found medically fit.

APPOINTMENT, PLACEMENT AND CAREER DEVELOPMENT

The candidates selected for the award of 'Dr K. S. Krishnan Research Associateship' would be appointed for a period of one year and based on their actual performance, they may be permitted to continue their Associateship for 2nd year. The Research Associates will be paid a consolidated sum of **Rs 10,500/-** per month and other benefits (Medical benefits and Casual leave). Hostel accommodation during the period of Associateship will be provided. Selection of Dr K. S. Krishnan Research Associates will be done by Committees appointed by BRNS. During the period of associateship, the concerned DAE unit, where they are working will evaluate their performance and if found suitable, recommend them for an appropriate position in the DAE. Appointment will be subject to availability of vacancies and recommendation of an appropriate DAE selection committee based on an interview. Appointment in a unit of DAE will be in the pay scale: Scientific Officer/Engineer-D (**Rs 10,000-325-15,200**). Award of additional increments will also be possible. Exceptionally brilliant candidates with excellent track record in advanced technologies of relevance to DAE and having a Ph D may be considered for the pay scale: Scientific Officer/Engineer-E (**Rs 12,000-375-16,500**).

Total emoluments at present in the minimum of the scale inclusive of House rent and Transport allowances (if applicable) in a Class-A city are Rs 17,300/- for Scientific Officer/Engineer-D and Rs 20,540/- for Scientific Officer/Engineer-E.

HOW TO APPLY

a. The application should be submitted on a plain paper as per the proforma given in the advertisement preferably typewritten. Affix a passport size photograph with signatures across on the application form (Top right corner) and attach one spare photograph.
b. Attach only the photocopies of the following documents or certificates duly attested by a Gazetted Officer/Head of

the Institute (Do not enclose original certificates with the application).

- i. CBSE/HSC/SSC/Matriculation certificate in proof of date of birth.
- ii. All degree certificates and mark sheets in support of qualifications.
- iii. Certificate to support the claim of belonging to SC/ST/OBC.

c. Enclose a self-addressed envelope (15 × 25 cm) affixing Rs 6 stamps and a Postal Order/Demand Draft of Rs 50/- drawn in favour of Accounts Officer, BARC payable at Mumbai towards application fee. SC/ST and Wards of Defence Personnel killed in action are exempted.

d. Persons working under the Central/State Government/Public Sector Undertakings should submit their application through proper channel.

e. Send application by Registered Post with Acknowledgement to reach the following address on or before 10 June 1999 indicating the advertisement No. on the envelope: **Deputy Establishment Officer (R-IV), Bhabha Atomic Research Centre, 4th Floor, Central Complex, Trombay, Mumbai 400 085.**

A BRIEF NOTE ON BOARD OF RESEARCH IN NUCLEAR SCIENCES

Board of Research in Nuclear Sciences (BRNS) is an advisory body to recommend financial assistance to universities/institutions/laboratories with the objective to encourage and promote scientific research in areas of relevance to the mandate of the Department of Atomic Energy (DAE). BRNS plays a vital role in strengthening collaboration with educational institutions/universities to meet the scientific and the technological needs of the Department.

Main mandate of DAE is the production of safe and economical nuclear power, using indigenous uranium and thorium resources. Towards this end, it is involved in developing, in stages, pressurized heavy water reactors, fast breeder reactors, advanced thorium reactors with associated fuel cycle systems.

It builds research reactors for production of radio-isotopes and carries out programmes on isotope and radiation technology applications in medicine and agriculture and industry.

It develops advanced technology in areas like accelerators, lasers, control and instrumentation, computers, biotechnology, information technology and materials technology, etc. and also encourages technology transfers to other users and industry.

It supports basic research in nuclear energy and related frontier areas of science.

PROFORMA FOR 'DR K. S. KRISHNAN RESEARCH ASSOCIATESHIP'

1. Category applied for: Ph D (Science) or Ph D (Engg) or Masters in Engineering with 2 years experience

2. Area of specialization ____________________
(Enclose separate sheets indicating discipline and giving a brief description, max. 500 words, of the work done for Ph D or 250 words for the project work done for masters in Engg and 250 words to describe the work done after masters. For candidates who have not done project work during masters, description of only work experience may be given.)

3. Full name in capital letters

4. Nationality

5. Date of Birth | D / M / Y

6. Postal address including telephone no, fax no and email address if available.

7. Whether belong to SC/ST/OBC | YES / NO |
(If answer is yes please attach a copy of the relevant document)

8. Details of educational qualifications beginning with the latest degree. Give branch of specialization, Institute/University, Year of passing and marks obtained.

9. List of research publications (in the following format: title, authors, name of the journal/conference proceedings, volume, page). Please enclose up to five selected reprints.

10. Name and address of two referees who are familiar with the work done by the candidate.

11. DD No., Name and branch of the Bank/Postal Order No.

12. List of documents attached

DECLARATION

1. I hereby declare that all the statements made in the application are true to the best of my knowledge and belief.
2. I am aware that my application is liable to be rejected, if the information given above is incomplete or found to be incorrect.

Date: Signature of the candidate
Place:

Government of India
Department of Atomic Energy
Board of Research in Nuclear Science
Trombay, Mumbai 400 085

GOVERNMENT OF KERALA
SCIENCE, TECHNOLOGY & ENVIRONMENT DEPARTMENT

POST: DIRECTOR, Agency for Non-conventional Energy and Rural Technology

Applications are invited to the Post of Director in ANERT, an autonomous Research Institute established by the Government of Kerala under the Science, Technology and Environment Department. The Institute is responsible for carrying out research on all aspects of Non-conventional Energy Sources & Rural Technology.

The Director is the Chief Executive with full authority and responsibility to organize and manage the staff, finances, facilities and services of the Institute, to meet its goals and objectives within the policy guidelines set for by the governing body nominated by the Government. The candidate must possess ME/M Tech with 17 years Research and Development experience or Ph D (Science) with 16 years Research and Development experience or Ph D (Engineering) with 14 years Research and Development Experience.

Experience: Areas related to alternative Energy and Rural Technology.

Candidates must be preferably below 55 years of age. The scale of pay is Rs 18,400–22,400 with allowances as per CSIR norms. Appointment will be made on contract for a term of 6 years (which may be extended further in exceptional cases) or until super annuation at 60 years of age, whichever is earlier.

Applications with complete bio-data and a list of Scientific Publications may be sent to the Director, Science, Technology and Environmental Department, Government of Kerala, II Floor, CMD Buildings, Thycaud, Thiruvananthapuram 695 014, within 15 days from the date of publication of this notification.

Sd/-
Chairman, STEC & Ex-officio Principal
Secretary to Government

INDIAN NATIONAL SCIENCE ACADEMY

Bahadur Shah Zafar Marg, New Delhi 110 002

INVITATION FOR NOMINATIONS

Nominations are invited for the award of **Indira Gandhi Prize for Popularization of Science** for the year 2000.

The Prize will be awarded for outstanding work by an individual for the popularization of science **in any Indian language, including English.** The nominee must have had a distinguished career as a writer, editor, journalist, lecturer, radio or television programme director, film producer, science photographer or as an illustrator, which has enabled him/her to interpret science (including medicine), research and technology to the public. He/she should have a knowledge of the role of science, technology and research in the enrichment of cultural heritage and in solution of problems of humanity. Work already recognized for any other award will not be accepted.

The prize is open to any Indian national residing in the country and will carry **Rs 10,000/- in cash and a bronze medal.** The prize winner will be expected to deliver a lecture at the venue to be fixed by the Academy. Nominations for the award of Prize may be made by the **Fellows of INSA, Vice-Chancellors, Directors of leading scientific institutions and National Laboratories and Editors of Indian Science Journals** in the prescribed proforma which will be supplied on request.

The nomination form may be obtained from Executive Secretary, Indian National Science Academy, Bahadur Shah Zafar Marg, New Delhi 110 002, and after its completion and duly accompanied with relevant documents be submitted at the same address latest by **15 July 1999.**

Government of India
Department of Biotechnology
Ministry of Science & Technology

National Bioscience Award: 1998–99

Corrigendum

With reference to the above titled advertisement which appeared in *Current Science*, Vol. 76, Number 5, 10 March 1999, the readers are requested to note the following changes/modifications made in the Scheme:

(a) The awards will be called as 'National Bioscience Awards for Career Development'. Scientists may be nominated who are currently engaged in basic and applied research in Biosciences/Biotechnology including agriculture, biomedical and environmental sciences and product and technology development.

(b) Each awardee will be provided a research grant of Rs 3 lakhs per year for a period of 3 years in addition to the award money of Rs one lakh and a citation.

(c) Each nominee should submit a brief research project proposal not exceeding 2 pages.

(d) The last date for receipt of nominations has been extended to 30 June 1999.

(e) The nominations should be sent to the Adviser, Human Resource Development, Department of Biotechnology, Block 2 (6–8th floor), CGO Complex, Lodhi Road, New Delhi 110 003 so as to reach on or before 30 June 1999.

(f) Those who have already applied against the above advertisement need not apply again. However, they should send a brief research project proposal not exceeding 2 pages.

CD-ROM Databases
from INSDOC
for R&D Institutions

National Union Catalogue of Scientific Serials in India on CD-ROM

The NUCSSI database is a valuable information tool that not only provides information on location of serials but also helps in their rationalised acquisition by encouraging resource sharing. The CD-ROM contains information on holdings of nearly 450 libraries in India with an update status of 1997. The database has a user friendly menu driven access and is searchable through various options like journal title, library, city and subject.
Price: Rs 6,000/- only

Indian Patents on CD-ROM

The INPAT on CD-ROM is a bibliographic database that provides information on nearly 52,000 patents granted in India from the year 1972 to December 1998. Information on a patent in the database comprises: patent title, applicant and inventor names, patent and application numbers, application and publication dates, international classification code and country. The database can be searched by a variety of parameters including keywords, applicant names, patent names, etc.
Price: Rs 10,000/- only

The two CD-ROM databases proved to be very useful to scientists, technologists, researchers and information professionals and are extensively used in the libraries of R&D centres and S&T institutions.

The retrieval software in both the CDs is Windows 95 based and is very user friendly.

Hardware/Software requirements: Pentium system with 16 MB RAM, CD-ROM drive, SVGA Colour Monitor, Windows 95.

Place orders with:

Assistant Head
Marketing and Customer Services Division
Indian National Scientific Documentation Centre
14-Satsang Vihar Marg, New Delhi 110 067
Phone: 686 3617, 656 0141 Fax: 686 2228
E-mail: mcs@sirnetd.ernet.in, mcs@del3.vsnl.net.in

DEPARTMENT OF BIOTECHNOLOGY
MINISTRY OF SCIENCE & TECHNOLOGY
GOVERNMENT OF INDIA

INDIA–ISRAEL SCIENTIFIC RESEARCH COOPERATION
Inviting Project Proposals in Human Genome Research

Department of Biotechnology invites project proposals relating to Human Genome Research under the Indo-Israel bilateral scientific programme on the following topics:

1. Genetic disorder and their treatment;
2. Population diversity-polymorphism in the human genome;
3. Human genomics and functional genomics; and
4. Technologies for genetic therapy.

Co-operation will be in the form of Joint Research, complementary methodologies, approaches to solve common problems and use of research facilities carried out in the Indian and Israeli laboratories.

The project should be planned for two years and may include manpower for project (excluding regular member of staff) overheads, equipments, consumables and mutual visits.

The project investigator must be affiliated to an academic institute/research institute/university. The project investigators will be responsible for executing of research work throughout the duration of the project. Researchers from industry may take part in the programme as partners in teams headed by Principal Investigators from an academic institution or research institute.

The completed proposals must be submitted in English in the prescribed forms in 20 (twenty) copies not later than 1 August 1999.

Prescribed format for submission of project and other details may be obtained from Dr S. R. Rao, Principal Scientific Officer, Department of Biotechnology, Block 2, 7th Floor, CGO Complex, Lodhi Road, New Delhi 110 003. (Tel: 4360064; Fax: 011-4362884).

Current Science

SUBMISSION IN ELECTRONIC FORM

Authors who have been informed of acceptance of their manuscripts may send the final version in electronic form on floppy diskette (3.5″ preferred; IBM PC format only, *not* Macintosh). The text of the manuscript only should be supplied as a plain ASCII file with no formatting other than line and paragraph breaks. (Wordstar 5.5 or 7.0 and Microsoft Word for Windows 6.0 are acceptable, but ASCII is preferred.) A hard copy of the text, with all typesetting information (italics, bold, mathematical type, superscripts, subscripts, etc.) must accompany the electronic copy. Tables and figures must be supplied only as hard copy. The diskette must be labelled clearly with the following: manuscript number, file name, file information (ASCII or Wordstar, version number, etc.)

Text may also be transmitted as ASCII only by e-mail to currsci@ias.ernet.in.

We expect that electronic submission will result in quicker processing for publication.

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A fortnightly journal of research

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